MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

The Geology *of* Hazara *and the* Black Mountain, *by* C. S. Middlemiss, B.A., *Geological Survey of India.*

CHAPTER I.—INTRODUCTION.

BEFORE beginning the purely descriptive portion of this Memoir a few words are necessary to explain how I came to undertake the work, and the nature and scope of it.

The detailed geological surveying of the district of Hazara was begun by me, after a lapse of about a decade, at the instigation of the Punjab Government, who were anxious for further information about the coal of the Dore river, as to the worth or worthlessness of which, opinion was divided. It was whilst investigating the conditions under which this carbonaceous band occurred in the valley of the Dore and in the neighbouring parts of Hazara, that there gradually accumulated a mass of miscellaneous geological details, in one way or another connected with the special information wanted, and which ultimately led to my continuance in the district to complete a general account of the geology of Hazara.

Although I have examined in detail almost every section that will be described in the sequel, it must not be forgotten that Hazara has already had its geological exponents, the chief of which, Mr. A. B. Wynne, late of the Geological Survey of India, is the one who first brought anything like order out of the chaotic rock-elements of this mountainous tract. It was he who, with the palæontological and field

assistance of Dr. Waagen, who was then in India, first seriously attacked the geological problems of the district in the vicinity of Abbottabad; and it was he who, during several seasons, from 1877 to 1879, intermittently and gradually built up, through the medium of a series of papers in the "Records," an effective outline of the geology of the whole area. An unfinished and unpublished geological map on the scale of ¼ inch = 1 mile was contemporaneously produced.

It seemed a pity that so much good work should suffer from being in so disconnected and unfinished a state, and hence my detention in this part of the country to complete the survey.

Thus engaged, my main duty has been to link together by fresh work in the field all the observations of Mr. Wynne and others, and to present them in a connected form in this Memoir. I have conscientiously striven to follow along the lines laid down by Wynne and Waagen, to see everything they saw as far as possible, and, by picking up the threads of their work wherever they were broken or missing, to supply an organised account of the geological fabric of Hazara.

There will naturally be found some few points on which I have had to differ from previous investigators, but they are not many. Besides being my duty, I am happy to state that it has been a congenial task to follow out by mountain and glen, by ridge and river, the work so well begun, but unfortunately unfinished by my predecessors.

I do not know that I need offer any further apology for the presence of this book. To those who will open it with the hope of finding glowing descriptions of an "Eldorado," from the drainage of which the Indus and Sohan rivers "roll down their golden sand," I can promise nothing but disappointment. I can only humbly refer them to those general principles enunciated by Ball [1] on the subject, where the apparent paradox of auriferous river-beds in a reefless

[1] Manual of the Geology of India, pt. III, p. 173.

country is clearly explained. To others again who seek for information about the more useful minerals, I can only say that the outlook is not encouraging. The connection between mountains and mineral wealth has by long experience been shewn, so far as the Himalaya are concerned, to be an unnecessary relation; and the case of the Hazara mountains, whose rock-foundations are similar, if not identical, seems to be the same; whilst even were it not so, a few high hill ranges, deep valleys, and capricious torrents are a greater obstacle to the development of a coal or iron industry than hundreds of leagues of ocean or miles of plain, in these days of rapid international communication! The little there is to say about the coal and iron of the district will be found in the appendix, page 286.

Happily towards the close of this nineteenth century it is becoming less necessary for scientific research to shew an immediate harvest material gain, by way of justifying its existence. On the principle that we never know when abstract knowledge may become of practical use, pure geological surveying, to fill in the blank spaces on the map of India, is now receiving all necessary encouragement from influential quarters.

As a small contribution to the further knowledge of the structure of the earth's crust along the fringe of a great mountain system, and as a link between the geological descriptions of the Rawalpindi and Jhelum districts and that of Kashmir, the present work is issued in the hope that it may be of some interest to the scientific reader.

Working parties. Seasons.

Dr. King, late Director of the Geological Survey of India, first introduced me to the geology of this frontier district in the summer of 1890. He had occasion to pay a visit here during his annual tour of inspection in order to decide on the course to be adopted with regard to the coal of the Dore river. As I was in the Punjab (Salt-Range) at the time, he took me with him, and subsequently left the further investigation of the same in my hands. This occupied most of the hot weather and rainy season of 1890. The cold weather of 1890-91 I spent alone in Hazara, until the Black Mountain campaign, which

began in March, enabled me to push my survey across the border into the almost unknown country of the Hassanzai and Akazai (small trans-frontier tribes). This season's work, both before and during the campaign, was considerably interfered with by persistent bad weather—rain, hail, snow, and high winds frequently stopping work. In the following cold weather of 1891-92 Sub-Assistant Hira Lal was placed with me, and I was joined a little later by Mr. W. B. D. Edwards, A.R.C.S., late Assistant Superintendent, then newly arrived in India. The season was unusually mild and favourable for work, and great progress was made with the map. During the last working season, 1892-93, I again had the services of Sub-Assistant Hira Lal. The cold weather began well during the latter part of 1892, but at the end of January and during most of February 1893 heavy snowfall of phenomenal severity drove my field operations to lower and lower levels, until not only the higher hills, but Abbottabad, the low fringing hills north of Rawalpindi plateau, and all the lowest parts of the Haripur plain, were covered with snow, the rivers flooded, and camping at last rendered impossible. The heavy snowfall also prevented certain projected trips up into the higher valleys of Bogarmung and Khagan, for though the route along the valley of the Koonhar was more or less open, the hill-spurs and ridges were hopelessly buried under snow. Even so far south as the ridge between Kalabagh and Tandiani the northern slopes and crests 8,000 and 9,000 feet high were similarly covered with a deep and impassable mantle until late in May. As an additional check to work, the rains set in earlier than usual and with terrible violence. It will be a long time before the rise of the Jhelum river in July, 36 feet above its mean summer level, and which swept away the Domel, Garhi-Habibullah and Kohala bridges, will be forgotten.[1] All communication between Hazara and Kashmir was cut off thereby, and much additional

[1] From information supplied by Mr. R. B. Yates, Ex. Engineer, Rawalpindi Pro. Circle, this flood was 63 ft. above winter level, 36 ft. above mean summer level, and 15 ft. higher than any previously recorded flood.

damage to land and property caused; the railway was breached by the Haro river near Hassan Abdal; the Jhelum and Rawalpindi districts were deeply flooded; there were landslips at Murree and on the "gulee" roads, and great loss of life to man and beast.

It will be gathered from the above that besides the ordinary difficulties of surveying in a mountainous tract my party were often subjected to the unusual discomforts and annoyances of a capricious climate, which on two or three occasions, wind and rain combining, left nothing standing in camp, and converted our tents into soiled and limp rags spread in confusion on the ground, among the tangled ropes of which and in the darkness and hurricane we were constrained to keep a dismal watch.

Maps, section, &c.

The maps used for work in the field were those of the Revenue Survey on the scale of 1 inch=1 mile for the district of Hazara. In the Black Mountain a map on the scale of ¼ inch=1 mile was alone available. The geologically coloured map of Hazara, accompanying this Memoir, is on the scale of ½ inch = 1 mile, and has been specially reduced for this Memoir by photozincography from the 1 inch=1 mile maps. The horizontal sections are drawn on the scale of 4 inches=1 mile (horizontally and vertically). In their construction the heights marked on the map have been taken wherever possible. As these, however, are not so numerous as one could wish, I had to supplement them by taking angles to known points and working out approximate results. Details of the hill outlines in the sections are either taken from pocket-book sections drawn by hand, or from outline sketches made with the *camera lucida*. In the sections the thicknesses of the formations must be taken as only approximate in the case of the larger formations. It is manifestly impossible, in a country so much disturbed and cut through by fold-faults, to make tape measurements, or any other closely accurate estimation of thicknesses. I have endeavoured, however, to indicate the probable limits of error in the approximations given. The plates and panorama views are introduced to give the reader some notion of the surface

configuration of the country in relation to the geological structure. The plan adopted of colouring the plates with the same tints as used on the map[1] recommends itself to me as a simple and effective, though not altogether novel, way of shewing the individual formations, which are too much masked by forest and cultivation to present peculiarities that could be seized and represented in line-drawing alone, especially when viewed from a distance. All these were drawn with the *camera lucida* and may be trusted to give a faithful representation of the forms and slopes of the country without personal exaggeration. The sketch sections and diagrams are from pocket-book sections, and notes and data made on the spot. They are not drawn to any particular scale.

I may parenthetically remark that in the text of this Memoir I have generally adhered to the old spelling of names of villages, &c., because it is the spelling adopted on the accompanying map. Anyone can transform it into the more modern form of the Hunterian system by remembering that Hureepoor (pronounced like the English words "hurry" and "poor") would be written in that system Haripūr, and Punjab would be similarly written Panjāb. Names such as Hazara, Rawalpindi, etc., I have, however, written in the modern style.

Literature.

The following is a tabulated list of all the important contributions to the geology of Hazara that I have been able to find. It is chronologically arranged. As I have already acknowledged my indebtedness to the chief original workers in the district, I shall leave all discussion of points in which I have differed from the views and observations expressed by these writers, until I come to describe the individual sections in the body of the Memoir:—

Vicary, "On the Geology of the Upper Punjaub and Peshaur." Quart. Journ. Geol. Soc., Lond., Vol. VII, p. 38, 1851.

* Verchère, "On the Geology of Kashmir, the Western Himalaya and Afghan Mountains." Journ. As. Soc. Bengal, Vol. XXXV, p. 89, 1866; Vol. XXXVI, p. 28, 1867.

[1] Economy in printing the colours of the map has led to a slight alteration in them: the Infra-Trias coloured neutral tint on the drawings is a pale blue on the map.

Waagen, "Rough Section shewing the relations of the rocks near Murree (Mari), Punjab." Rec. G. S. of I., Vol. V, p. 15, 1872.

* Waagen and Wynne, "The Geology of Mount Sirban in the Upper Punjab." Mem. G. S. of I., Vol. IX, pt. 3, 1872.

Wynne, "Notes from a Progress Report on the Geology of parts of the Upper Punjab." Rec. G. S. of I., Vol. VI, pt. 3, 1873.

* Wynne, "Observations on some features in the physical geology of the outer Himalayan region of the Upper Punjab, India." Quart. Journ. Geol. Soc., Lond., Vol. XXX, p. 61, 1874.

Wynne, "Notes on the geology of the neighbourhood of Mari hill station in the Punjab." Rec. G. S. of I., Vol. VII, pt. 2, 1874.

Medlicott, "Note upon the Sub-Himalayan series in the Jamu hills." Rec. G. S. of I, Vol. IX, pt. 2, 1876.

* Wynne, "Note on the Tertiary zone and underlying rocks in the north-west Punjab." Rec. G. S. of I., Vol. X, pt. 3, 1877.

Theobald, "On the occurrence of erratics in the Potwar." Rec. G. S. of I., Vol. X, pt. 3, 1877.

Theobald, "Remarks, explanatory and critical, on some statements in Mr. Wynne's paper on the Tertiaries of the north-west Punjab." Rec. G. S. of I., Vol. X, pt. 4, 1877.

Stoliczka and Blandford, "Scientific results of the Second Yarkand Mission." Calcutta, 1878.

* Wynne, "Further notes on the geology of the Upper Punjab." Rec. G. S. of I., Vol. XII, pt. 2, 1879.

Waagen, "Note on the Attock slates and their probable geological position." Rec. G. S. of I., Vol. XII, pt. 4, 1879.

Wynne, "On the continuation of the road section from Murree to Abbottabad." Rec. G. S. of I., Vol. XII, pt. 4, 1879.

Wynne, "Travelled blocks of the Punjab." Rec. G. S. of I., Vol. XIV, pt. 1, 1881.

* Lydekker, "Geology of north-west Kashmir and Khagan." Rec. G. S. of I., Vol. XV, pt. 1, 1882.

Feistmantel, "Note on remains of Palm leaves from the (tertiary) Murree and Kasauli beds in India." Rec. G. S. of I., Vol. XV, pt. 1, 1882.

* Wynne, "Further note on the connection between the Hazara and Kashmir section." Rec. G. S. of I., Vol. XV, pt. 3, 1882.

* Medlicott, "Sketch of the Geology of the Upper Punjab." Calcutta, 1883-84.

Gazetteer of Hazara District, 1883-84.

Gazetteer of Rawalpindi District, 1883-84.

* Lydekker, "The Geology of Kashmir and Chamba territories and the British district of Khagan." Mem. G. S. of I., Vol. XXII, 1883.

Waagen, "Section along the Indus from the Peshawar Valley to the Salt-Range." Rec. G. S. of I., Vol. XVII, pt. 3, 1884.

Middlemiss, "Preliminary note on the coal seam of the Dore Ravine, Hazara." Rec. G. S. of I., Vol. XXIII, pt. 4, 1890.

The more important papers, or those bearing more directly on the subject of this Memoir, are marked thus *.

Obligations.

My thanks are due in the first place to my fellow-workers Mr. W. B. D. Edwards and Lala Hira Lal, for much helpful assistance in the field, and for their cheerful furtherance of my plans. To the district officers and forest officers of Hazara I have also to express my great obligation, and especially to Mr. F. D. Cunningham, C.S., C.I.E., at that time Deputy Commissioner of Hazara, who was often able to give me much help in the more out-of-the-way parts of the country. To commanding officers and others during the Black Mountain expedition I also tend my thanks for escorts and other assistance. For suggestions and help with my collections of fossils and rocks I am much indebted to Mr. Griesbach, Director, and to Dr. Noetling and Mr. Holland, of the Geological Survey.

CHAPTER II.—STRATIGRAPHICAL ELEMENTS.

General.

It is usual in the Memoirs of the Geological Survey to begin the description of a country with some remarks on the surface features, physical geography, etc. If I seem to be departing from a good old rule here, it is for the reason that all particulars, such as cannot be gathered from an inspection of the map, will more consistently find a place in the following chapters, when I come to describe in detail the geology of each of the zones, or strike areas, into which I shall find it expedient to divide up the country. This seems the more desirable inasmuch as the very varied aspects of the country are so indissolubly connected with the geological components of the zones, that the former would be bare and meaningless if presented without their structural *raisons d'être*.

I may remark, however, that Hazara is a strip of generally mountainous country, bounded on the south by the Rawalpindi plateau, on the north by the little-known mountainous country belonging

to a number of warlike, independent hill clans, on the west by the Indus river, and on the east by Kashmir, with the Jhelum river below Domel as the line of demarcation.

Structurally, and therefore geologically, it connects the Rawalpindi and Jhelum districts (which embrace the Salt-Range) with the territory of Kashmir ; all of which have been geologically described in considerable detail by former members of the Geological Survey of India (see list of authors and works in the Introduction).

The table which follows shows the stratigraphical elements or formations which take part in the Geological Record of Hazara, arranged chronologically :—

Table of formations in Hazara (in descending order).

HISTORICAL ROCKS.

VIII.—*Murree beds*	Miocene	TERTIARY.
VII.—*Kuldana beds* (passage)		
VI.—Nummulitic series	Eocene	
V.—Middle Cretaceous = Chalk Marl and U. Greensand = Cenomanian		MESOZOIC.
IV.—Jurassic		
III.—Triassic		
II.—Infra-Triassic=Carboniferous or Carbo-Permian (?)		PALÆOZOIC AND PROBABLY OLDER.
I.—Slate series	Age unknown	

CRYSTALLINE AND METAMORPHIC ROCKS.

b. "*Tanol*"	Infra-Triassic in the main	PALÆOZOIC OR OLDER.
a. Crystalline schists	Equivalents of I and II above in the main,	
x. Intrusive gneissose-granite		
y. Intrusive dyke rocks		

From the above table the youngest Tertiary, or Siwalik formation, Pliocene, is absent, as it does not occur in Hazara, although it is well developed towards the south in the Rawalpindi plateau. From the Murree beds to the Jurassics the Geological Record in Hazara is fairly complete, save that Upper Cretaceous rocks (if represented) are not marked by any fossil zone ; and that the Jurassics, if lithological identity with other parts of India is disallowed as evidence, cannot be subdivided more closely into life-zones.

With the Trias comes a small, though consistent, stratigraphical break. The evidence for any trustworthy subdivision of the Trias is wanting, or very doubtful.

At the base of the Trias there is another stratigraphical break, and it seems certain that all representatives of the great Carboniferous, or Carbo-Permian epoch, so well developed in Kashmir and the Salt-Range, are either completely absent in Hazara or are represented by the unfossiliferous Infra-Trias limestone (but see p. 29).

With the so-called Infra-Trias we enter on unfossiliferous rocks of unknown age; but a comparative study of other Indian regions gives us a possible clue to the age of its lowest member (see p. 19 *et seq.*).

Below the Infra-Trias is a great stratigraphical break with total unconformability upon the great azoic Slate series beneath.

The crystalline and metamorphic rocks exhibit a Himalayan facies as regards the crystalline schists and intrusive sills of gneissose-granite and the basic dyke rocks; but the great thickness of subaerial volcanic rocks of Palæozoic age, exposed in Kashmir, are not known in Hazara.

The following details have sole reference to the petrology, normal succession, lateral variation, age, and palæontological position of the formations and rock-masses in Hazara. I propose to begin with the lowest known of the stratigraphical or historical rocks, that is to say, the Slate series, and to work through the formations one by one in ascending order. The crystalline and metamorphic rocks, though connected with the historical rocks in a definite way, will be treated separately as a distinct branch of the same subject, after the normal unmetamorphosed series and groups have been described.

HISTORICAL ROCKS.

(I) SLATE SERIES.

Generalities.

The oldest known rocks in Hazara consist of a great series of thin-bedded, argillaceous, and slightly arenaceous deposits, which in the most typical parts of the district are known in general terms as slates. Their dark and

sombre colouring, the fineness of the sediment of which they are composed, their highly fissile nature and hardness, together with the fact that no other beds of slate occur subsequently among any of the higher groups of strata, give to this great formation a characteristic unity of aspect that marks it off completely from all the rest of the formations which follow above it. In the northern parts of Hazara these rocks have suffered conspicuously from dynamic and regional metamorphism, and have become converted into crystalline schists, just as have some of the lower members of the groups which next succeed them; but, as already stated, it will be more convenient to treat all the metamorphic rocks together at the end of this chapter.

Colour.

The neutral colours of the Slate series approach most nearly to dark blue-grey in tone. Some few slates are, however, of an olive or greenish-grey, while occasionally they possess a purplish tinge. None of the members of this series, except some among the schistose varieties where they are impregnated with graphite, have a dead-black colour or anything to especially indicate carbonaceous admixture.

Composition.

In composition they may be regarded as impure sandy slates with many interbedded bands of fine grit and quartzite, also of dark neutral colours. Occasionally, as south-west of Sirban hill, softer greenish micaceous and earthy sandstones are regularly bedded with the slates. Here and there also faint traces may be detected of a fine local conglomerate, among the pebbly layers of which there are some grains of dark quartzite.

Limestone interbanded with the slate.

In certain areas among the Slate series there occur very subordinate limestone bands. Abundant local sections shew them to be truly interbedded with the slates, and they seem to die out in certain directions and in others to increase in thickness to as much as 60 or 80 feet. Their exact horizon among the slates is not known, inasmuch as the Slate series itself is so uniform in petrological characteristics, and so much disturbed and contorted, that in the absence of fossils no

means of recognising horizons among it have been discovered. The most prominent band occurring in the slates is especially well developed near Lungurial, and it may be called the Lungurial band for future reference. It is a concretionary limestone, extremely hard, very impure, and of a dark blue-grey colour. The parts of the matrix which wrap round the concretions have resisted weathering more than the concretions themselves, so that they stand out on the exposed surfaces as a pale rusty ochre or dark-brown mesh-work. The rough and pseudo-scoriaceous blocks which thus result are very characteristic of this rock. Another band of calcareous rock appearing among the slates is found quite near to the last; and is of a flesh-white or reddish colour, and marble-like texture. In some places it becomes very much brecciated. I have referred above to the graphitic layers which occur among the slates where they are becoming slightly schistose, as in the Gundgurh range and elsewhere. They appear intimately connected with some of the interbedded limestones, and some of the latter are also impregnated with carbonaceous material. They will be more fully described in connection with the metamorphic rocks.

Structure of the slates.

Although there is no other petrological term that would express the characters of these rocks except the word slate, it is nevertheless true that anything in the shape of a good slate, using the word in its economic sense, is practically unknown. Nowhere does the rock split up into fine leaves or folia suitable for roofing purposes. On the contrary, although the rock has undoubtedly been cleaved, sometimes across, and sometimes with the bedding, so that it is a slate in the sense of being an argillaceous rock which owes its fissibility, not to original bedding, but to subsequent re-arrangement of the particles by pressure, yet this arrangement is not perfect enough, nor is the rock pure enough for the production of a good slate. Another cause seems to be the fact that the rock has been cleaved in more than one direction, so that a second cleavage, often spoiling and replacing the first, has resulted in the rock assuming a splintery condition.

Absence of fossils in the slates.

Vast as must be the thickness of these slates, they have yielded no fossil remains of any sort, so far as all reliable evidence goes. Dr. Waagen[1] has, however, strongly advocated the claims of certain Carboniferous fossils found among the collection of the Geological Society of London, and which are imbedded in a "black slate" and labelled "Panjab" as belonging to the Attock slates (the probable continuation of my Slate series). After a long acquaintance with the slates of Hazara, and also with what I am inclined to think identical rocks in the Himalaya, I do not feel myself that the lithological character of a few specimens simply labelled Panjab is sufficient ground for calling the Attock slates or their Hazara equivalents Carboniferous. If it were so, then the Silurian fossils said to have been found by Dr. Falconer[2] in river boulders in the Kabul river, and imbedded in a similar slate rock, would also have the same title to recognition as evidence in the case, or perhaps more so, as their locality is more definitely fixed.

But although neither of these shreds of evidence can be deemed sufficient for the purpose of fixing the age of these slates, it is well to keep them in mind as pointing to possible, if not highly probable, conjectures.

The fossils mentioned by Wynne[3] from some limestones near Dakner, and at the Mirkulan pass, are untrustworthy from the fact that it is uncertain whether the limestone is an integral part of the Slate series, or merely appears in the section caught along the axis of a sharp fold. Many instances of the latter kind may be seen in Hazara.

On page 116 of the new edition of the Manual of the Geology of India Mr. R. D. Oldham alludes to synclinal folds of this nature; but it must be remarked that there is no confusion on the

[1] Rec. G. S. of I., Vol. XII, p. 183, 1879.
Godwin-Austen, Quart. Journ. Geol. Soc., Lond., Vol. XXII, 1866.
Rec. G. S. of I., Vol. X, p. 227.

ground between the older slates and the enfolded secondary rocks; each is quite distinct, and the necessity mentioned by him for colouring as palæozoic these large areas, although they contain folds of secondary rocks, is a mechanical one, due to the small scale of the Manual map relative to the sharp flexuring of the country. I wish to draw attention to this point somewhat closely, because Mr. Oldham's language leaves a faint suspicion behind that the occurrence of these enfolded secondary rocks might perhaps after all give the index to the true age of the enfolding slates, which may, therefore, themselves be secondary. This, however, in Hazara certainly, is far from being the case; the Slate series is one thing, and the fossiliferous rocks are another, quite distinct and separable, on a large-scale map, the one from the other.[1]

This absence of fossils in the Slate series does not seem to be owing to the fact that the rock has been cleaved to such an extraordinary extent as to have obliterated all traces of life, for many of the interbedded fine dark quartzites and grits shew no profound deformation of their grains, but on the contrary evince all the ordinary characteristics of a sedimentary rock that has accumulated most probably at the bottom of a tranquil sea. Nor for the matter of that is it at all a recognised fact that cleavage alone can completely obliterate all traces of organisms in a rock. It is well known to be able to distort and deform fossil remains, to draw them out in one or two directions, and to flatten them in another, but that it can altogether destroy them without leaving a trace over so great an area and through so great a thickness as the Slate series commands is, I think, not proved.

Age and stratigraphical position.

Under these circumstances it is a little difficult to assign to this great series a definite stratigraphical position, or to correlate it as regards age with standard palæontological horizons; and in order to do so, even approximately, we must use the indirect methods of reasoning which belong to comparative geology.

[1] That this was Wynne's matured belief, see Rec. G. S. of I., Vol. XII, p. 121.

In the first place there is the striking fact that the slates underlie the Infra-Trias, and therefore the Trias of Hazara. This is a relation that cannot be called in question (see remarks on the base of the next rock group), for a great unconformity divides the two formations. In the second place as regards their composition, structure, great thickness, and wide distribution they appear to resemble much of the Panjal system of Kashmir (Lydekker), and they most certainly are identical in the above characteristics with the great azoic slate and schistose slate formation of the Outer Himalaya of Garhwal and Kumaun (Middlemiss) and the corresponding Vaikrita, and perhaps in part Haimanta systems of the Central Himalaya (Griesbach). In the first of these compared areas the slate formation is known to underlie the Kuling = Carboniferous series, whilst in the last it underlies rocks in which Silurian fossils have been found: and there is no repetition in any of these regions of a similar great slate series higher up among the younger historical rocks.[1] Lastly, in the Salt-Range of the Panjab, the lowest known fossiliferous rocks are presumably Lower Cambrian in age since they contain an *Olenellus* fauna; and here, also, above that horizon we have no trace of anything of the nature of a great slate series, and, so far as the earth's crust is exposed beneath those Cambrian rocks, there is also no slate series exposed below that horizon.

Putting the above facts in order we may deduce the following:—

(1) That where a similar slate or schistose slate series is known in India, it always occurs *below* the oldest known fossiliferous rocks of that part, and never *above* any one of them.

(2) That as regards the Salt-Range, where the most perfect evidence of stratigraphical superposition is obtainable, if any slate series exists at a great depth below the oldest

[1] Mr. Griesbach, however, tells me of a remarkable occurrence of nummulitic rocks and others in Baluchistan converted by the intrusions of traps into schists and phyllites.

exposed rocks, then it must be at least of L. Cambrian, and possibly of Pre-Cambrian age.

In consequence of the above, these azoic slates must be considered to be very old, as old or probably older than the oldest known fossil-bearing rocks.

Relation to Attock slates.

Mr. Wynne in his papers on Hazara called this series the "Attock slates," from the circumstance that along the Indus at Attock they are particularly well exposed. From a cursory examination of the Attock section, and from considerations of a general nature, I have no doubt that the Hazara slates continue directly and unbroken to Attock. As this, however, has been called in question by Mr. Griesbach from observations made in the Cherat hills, and as the advantages to be derived from naming one great unknown after another great unknown are very questionable, I need say no more on this head.

Relation to the Kashmir Panjal system.

As regards Kashmir, the correlation of our Hazara slate series with the Panjal system of Lydekker is a natural and perfectly safe one. Lydekker[1] was also of the same opinion. He found from observations of his own that the schists in the Khagan valley were the same as his "newer gneiss" series, and that these were the metamorphosed representatives (at least in great part) of the "Attock slates," and that both corresponded therefore to the slate series of Kashmir. Lydekker in the same paper, p. 24, expressed his opinion that the contention of Dr. Waagen that the slate series of the Panjab generally may be Carboniferous, on the strength of the fossils referred to above, is an unwarranted contention. In justice to Dr. Waagen, however, it must be mentioned that when he wrote the note in the "Records" embodying that view Mr. Griesbach's Himalayan work was not begun, and the shales which subsequently yielded *Olenellus* under Khusak fort were believed by the former to be a part of the Productus Limestone group. Finally, Wynne expressed himself as

[1] Rec. G. S. of I., Vol. XV, p. 23, 1882.

generally inclined to agree with Lydekker in the above correlation, but he would rather suppose the schistose rocks of the Khagan valley to be equivalent to the lower part of the Attock slates, the degree of metamorphism depending on the depth of the horizon.

(II) Infra-Trias series.

Generalities.

Between the Slate series and the next younger formation there occurs a great stratigraphical and physical break, which is nowhere bridged over by intervening deposits so far as my investigations and those of my predecessors in Hazara have gone. The lowest of the younger series not only begins as a great coarse basal conglomerate suggestive of a shore-deposit, but it rests in complete unconformity upon the underlying slates.

Classification.

The Infra-Trias series may be divided up into the following stages in descending order—

			feet.
(3) Upper limestones	thickness	2,000
(2) Lower sandstones and shales	do.	150
(1) Basal conglomerate	do.	50—100

(1) *Basal conglomerate.*

Petrology

This conglomerate, to which Wynne and Waagen first called attention,[1] rests unconformably on the upturned edges of the Slate series. These observers have spoken of the rock as a "breccia"; but, from the fact that they clearly recognised its detrital origin, it must be understood that they used the word in the sense of an angular conglomerate. As the word breccia has however, the more usual and totally different meaning of a rock broken *in situ* by a faulting or other earth

[1] Mem. G. S. of I., Vol. IX, pt. 3, 1872.

movement, I prefer to speak of it as a conglomerate; a term perfectly applicable, whether we consider it as a petrological definition, or as implying its mode of origin. The deposit is essentially composed of fragments of the underlying slates and quartzites set in a fine purple sandy clay, or shale. The size of the fragments average about that of a cricket-ball, but they vary from mere pebbles to large lumps that one could barely move with both hands. The pebbles or boulders are generally sub-angular, and in this respect they have a certain resemblance to the material forming a glacial moraine or boulder-clay; but I was unable to discover on them any scratches or striæ by which the agency of ice as a transporting power could be deduced with certainty. The conglomerate is roughly but distinctly bedded, layers of finer and coarser material alternating with one another. The lowermost bed is very much coarser than the higher ones, the latter gradually becoming of less importance and of finer material; until by the complete disappearance of the finer pebbles the next stage of the series is entered upon.

Thickness.

The total thickness of the conglomerate in its most typical development at the south-west end of the Sirban hill-mass is 50—100 ft.

Range and lateral extension.

In common with the whole of the Infra-Trias series the basal conglomerate has a small visible lateral extension. This is partly owing to the overlapping of the next higher series (Triassic), and partly to the want of good exposures in the country to the north-east of Abbottabad. In a northerly direction this conglomerate, and also the whole of the Infra-Trias, have become considerably metamorphosed. They, with the metamorphic representatives of the Slate series, will be described at the end of the chapter.

No fossil remains.

No palæontological evidence is forthcoming as to the age of this conglomerate, nor of any of the succeeding stages of the Infra-Trias. As in the case of the Slate series we have one direct fact only to go on, namely, that they

underlie beds of Trias age, and that therefore they are older than those Trias beds. But all attempts at a closer limiting of their position must be of a somewhat speculative nature.

Possible homotaxis of the conglomerate with the boulder-bed of the Salt-Range.

There is one hypothesis, however, of a very suggestive nature to which Mr. Oldham has referred in the Manual, but without more than a passing comment,[1] *viz.*, that of the conglomerate being homotaxially related to the Boulder-bed of the Salt-Range. In the days when Wynne and Waagen worked in Hazara the Boulder-bed of the Salt-Range was believed by them to belong to the Cretaceous epoch, and as such it could of course have no affinity with beds lower than the Trias. But I cannot help thinking that had the above authors seen this conglomerate with our present knowledge of the Carboniferous or older age of the Boulder-bed before them, they might have been tempted to provisionally correlate the two. It is often remarked that a shore deposit like this conglomerate can never be contemporaneous with a similar deposit in another place, even in the extreme case of the bed being in continuous exposure between the two places. This is no doubt true, if we take our time-units sufficiently small. On the other hand if we look at the case broadly (as we are bound to do in the absence of characteristic fossils) we may quite reasonably correlate homotaxially two such formations in distinct but nearly-related districts, provided (1) that there is no general palæontological data opposed to it, and (2) that the petrological sequences involved in, and the physical conditions of the earth at the time implied by, those deposits, are analogous.

As I had the good fortune to spend a season in the Salt-Range just before proceeding to Hazara, and as the Boulder-bed and its relations were matters to which my attention was particularly directed, I may perhaps indicate in the following parallel columns the points of likeness and difference between the Infra-Trias basal conglomerate

[1] 2nd Edn., p. 138.

of Hazara on the one hand, and the Carboniferous Boulder-bed of the Salt-Range on the other:—

Hazara.	*Salt-Range.*
(1) The conglomerate is coincident with a great unconformity.	(1) The Boulder-bed marks a line of great overlap and slight unconformity.
(2) The pebbles are sub-angular, and vary in size from great masses to small pebbles, coarser below and finer above.	(2) The boulders are sub-angular, and vary in size in the same degree as those of the Hazara conglomerate.
(3) There are no ice scratches or facets visible on the pebbles.	(3) Ice scratchings, polishings, and facettings are common on the boulders.
(4) The conglomerate is a stratified deposit, and passes up into a purple sandstone.	(4) The Boulder-bed, though jumbled and chaotic at the bottom, becomes interstratified with and finally passes up into a pinkish sandstone, the Speckled Sandstone of Wynne.
(5) The pebbles consist entirely of local rocks belonging to the Slate series, which must have been exposed at the time.	(5) Although local fragments of rock, *e.g.*, Salt-pseudomorph bed, Dolomitic Sandstone, Purple Sandstone, are present, the boulders are chiefly composed of foreign crystalline and metamorphic rocks, evidently transported from afar and probably from peninsular India.[1]
(6) There is no other conglomerate of the kind exposed at any other horizon among the sedimentary rocks of Hazara.	(6) No other boulder-bed or conglomerate exposed at any horizon among the Salt-Range sedimentaries, except the insignificant one at the base of the Nahan stage (miocene).

Comparing these two analyses of the respective formations, we ave points (1), (2), (4), and (6) in which they agree, and points (3) and (5) in which the Boulder-bed exhibits a character which is wanting in the Hazara conglomerate: a character indicating the agency of transporting ice in some form, most probably that of glaciers. It may be noted, however, that if we were to add scratches, striæ, polishing, and facetting to the components of the Hazara conglomerate, it would at once become a "boulder-bed," so like are its other less important characteristics to one; whilst if we neglect those markings on the pebbles of the Salt-Range Boulder-bed, it at once

[1] See Middlemiss, Rec. G. S. of I., Vol. XXV., pt. 1, 1892.

becomes a "conglomerate," so similar is its general facies to a shore deposit of this nature. As regards point (5), if it be true that the material of the Boulder-bed came from the south, then the very old crystalline rocks of that part afforded abundant material; whilst in the case of the Hazara conglomerate the material could not have been derived from the crystalline rocks which now form the axis of the snowy-range to the north, because those crystalline rocks are younger than the Infra-Trias, and have in the northern parts of Hazara metamorphosed them, the conglomerate—pebbles and matrix together—being involved in dynamic and mineral change.

These points of difference between the two formations indicate a *difference* of conditions only, not a *disagreement*: the evidence of either is not contradictory to that of the other, but only supplementary.

The hypothesis, therefore, that the Hazara Infra-Trias conglomerate is homotaxial with the Salt-Range Boulder-bed, appears to me to be fairly reasonable.

Probable correspondence with the Panjal conglomerate of Kashmir (Lydekker).

I have dwelt upon this hypothetical relation of the two deposits, because of my familiarity with them both, and because the stratigraphical position of the Boulder-bed in the well-exposed sections of the Salt-Range is well known; but there seems to be little doubt that the Panjal conglomerate of Kashmir[1] is nothing but a continuation of the same deposit. In the Manual Mr. Oldham correlates the Panjal conglomerate with the Blaini conglomeratic slate of the Simla region, and he is of opinion that both are homotaxial with the Salt-Range Boulder-bed. Assuming that this is true, the argument deduced from the latter, that a great break must exist in the middle of Lydekker's Panjal series is further strengthened by the very marked unconformity in Hazara at the base of the conglomerate. I have not visited the Kashmir sections, but ten years ago, when with Mr. Oldham, I saw a good deal of the

[1] See Lydekker, Mem. G. S. of I., Vol. XXII, 1884.

Blaini conglomerate, and, so far as my memory and my notes serve me, I am disposed to believe in the connection between the Hazara Infra-Trias conglomerate and the Blaini conglomerate. It may be mentioned that the conglomerate in Hazara, further north than the typical locality of Sirban hill where metamorphic influences are beginning to tell upon it, has in many places more the character of a conglomeratic slate, inasmuch as the matrix has been hardened and the effects of cleavage go completely through the rock.

Talchir boulder-bed, Bacchus-marsh bed. Ecca bed.

Into the wider question of the correlation of each and all of these boulder-beds or conglomerates with the Talchir boulder-bed of South India, with the Bacchus-marsh beds of Victoria, Australia, and with the Ecca beds of the Karoo system in South Africa, I need not enter, as the question has been well threshed out by Mr. Oldham in the Manual.[1]

(2) *The lower sandstones and shales.*

Purple shales.

The basal conglomerate just described passes upwards into a purple shale. The passage from the one to the other is simply this, *viz.*, that whilst the pebbles of the conglomerate gradually diminish in numbers and size the matrix persists to form the purple shales.

Thickness.

The thickness of the shales is never very great, 20—30 feet at most, but it varies slightly as is natural.

Passing into sandstones.

The shales in turn pass upwards into a set of sandstones of considerable thickness.

The sandstones.

The sandstones are of a deep purple colour as a rule, but they frequently become white in their upper part when the rock has a saccharoid appearance. The texture of the rock is somewhat coarse. Bluish-grey chert veins are sometimes found traversing the rock along joint and beddi- planes.

[1] Chap. VIII, p. 198, *et seq.*

Possible correlation with the Speckled Sandstone of the Salt-Range.

In lithological appearance this rock has been noticed by Wynne and Waagen as very much resembling the Purple Sandstone (L. Cambrian at least) of the Salt-Range. If, however, our correlation of the conglomerate with the Carboniferous Boulder-bed be correct, these sandstones cannot be equivalents of the Purple Sandstone; but on the other hand they may very possibly represent the Speckled Sandstone, which in the Salt Range follows next above the Boulder-bed.

(3) *The upper limestones.*

Passage of the sandstones into the limestones.

At some places in the Sirban neighbourhood the sandstones just described pass gradually both by alternation and by change of material into the upper limestones which form the top member of the Infra-Trias series. The lowest member of the limestones is a deep purple very sandy limestone. After some interbeddings of sandstones and calcareous sandstones with purple limestones, the latter become less and less sandy, and at the same time change their colour to fainter tints of purple and pink. There are local variations in the amount of the colouring matter in the limestones, but generally as we rise into higher beds the colour pales, until it becomes of a white or cream colour. As far as I have seen, none of the limestones of this series are dark grey in colour or mottled as in the Trias series above; the colours are *always* purple, flesh-red, pink, white, or cream. There is, therefore, very little difficulty in distinguishing the one from the other in the field.

Colour.

Structure.

In structure the rock is generally extremely compact and well-bedded, more so than any of the other limestones that we shall have to deal with later. In the view of Sirban hill from the north (Plate 6) the well-bedded layers of rock dipping down the hill-slope to the right of the sketch are Infra-Trias limestone; as also are the marked scarps in the middle of the picture where the bedding is depicted with firm lines. In

band-specimens the rock is very characteristic, so characteristic that it would be almost impossible to mistake it for anything else when once the peculiarities have been mastered. These peculiarities consist chiefly in a fine cross-jointing which has been eaten into deeply by weathering, so that the blocks of the rock scattered about present an appearance very like that of a butcher's chopping-board which has become scored across and across in all directions by the knife. I do not remember to have seen elsewhere any surface weathering at all resembling this, which is so persistent as to at once arrest the eye. In the upper beds of the limestone there is a tendency to a vesicular structure on a small scale, the vesicles, which are about the size of pea, being filled with calcite.

Chert bands.

In the uppermost layers of the limestone there are many bands of chert lying parallel to the bedding. These bands appear to owe their presence chiefly to the metamorphic effects of the volcanic series which come next at the base of the Trias.

Composition.

Many of these limestones were called dolomites by Wynne and Waagen. A rough analysis of three samples, one from Shakur Bandee, a pink variety, (Registered No. $\frac{9}{579}$), one from Bandah Naiyan, and one from ridge north of Tanakki, vesicular variety (Reg. No. $\frac{9}{580}$), shows them to contain a small amount of magnesia, but not sufficient to make the rock a typical dolomite. The examinations were made by Mr. Blyth in the Geol. Survey Laboratory.

Beds of white felspathic grit.

Among the upper limestones there are here and there associated a few beds of white felspathic grit of no particular importance.

Partly confused with Trias by Waagen and Wynne.

Much of the Infra-Trias limestone of the north face of Sirban hill was confused with the Trias by Waagen and Wynne, in their memoir and map. In the descriptive part of this paper (see p. 101, *et seq.*) I have endeavoured to trace the origin of this mistake.

Possible Carbo-Permian age of the Infra-Trias limestone.

If we assume that the correlation of the Infra-Trias conglomerate with the Boulder-bed of the Salt-Range is a fair working hypothesis, then there is a reasonable probability that the Infra-Triassic limestone is a representative, partially or wholly, of the Carbo-Permian of the Salt-Range, Kashmir, Spiti, and Kumaun. The total absence of any of the fine fauna characterising that rock-group may not unwarrantably be accounted for by the metamorphism sustained by it, owing to the outpouring of the volcanic rocks at the base of the next series.

(III) Triassic series.

Stratigraphical position.

In such places as the Infra-Trias is exposed to view in the normal sequence of the rocks, the next succeeding formation, namely the Trias, makes its appearance under what at first appear to be conditions of some obscurity as to the exact relations of the series to each other. It will be duly proved, in the descriptive portion of this book, that the relation is a slightly unconformable one. Along the northern part of what will be described afterwards as the slate zone, it is generally the case that the Trias overlies one or other member of the Infra-Trias, but in the more southern parts of Hazara the former reposes directly upon the great Slate series.

With the Trias we begin an ascending group of formations embracing Trias, Jura, Cretaceous, and Nummulitic, which have been fixed as regards their palæontological position by the original workers in this area, Dr. Waagen and Mr. Wynne. This great group of secondary and tertiary rocks is very connectedly distributed, and generally when the Trias is found, the rest of the members of the group will also be found in superposition in the same cliff-section or hill-side.

The Trias may be divided up as follows :—

Classification.

(2) Trias limestone, 500—1,200 feet.
(1) Volcanic material, hæmatitic breccia, quartzites, shales, etc., 50—100 ft.

(1) *Volcanic material, etc.*

The volcanic material consists of a felsitic substance, which

most probably originally was a rhyolitic flow. At all events under the microscope it shews the fine-grained appearance of a microfelsitic ground-mass without any porphyritic crystals of orthoclase or quartz, or any other characteristic mineral or structure,—*e g.*, spherulitic or perlitic. Occasionally there is an indefinite wavy structure as if the remains of flow-structure, accompanied by a fibrous green mineral with strong double refraction running through the rock. At the bottom of this volcanic stage we have some very siliceous beds of grey and white colours, which seem to be of the nature of chert or some other amorphous form of silica, and to have been formed just as the chert bands in the upper parts of the Infra-Trias limestone were formed by the contact metamorphism of the felsitic flow on the limestone. Above this, on the north face of Sirban, come pink and white and greenish coloured felsitic rocks, banded in these colours, very tough to the hammer, with rough surfaces, and frequently exhibiting an appearance due, I think, to brecciation, a brecciation that has taken place as the material of the flow half solidified and then went on again. Some buff coloured, sometimes purplish, and micaceous shales follow above these, and then comes an earthy concretionary or pisolitic hæmatite associated with broken-up material from the felsitic rocks below. Some of this develops into a band 5 or 6 ft. thick of good earthy hæmatite, which would be useful economically if the coal of the neighbourhood should ever be successfully worked. A few quartzites occur here and there at uncertain horizons among these volcanic beds.

The thickness of this volcanic stage is not very great, never exceeding 50—100 feet. In the southern parts of the slate zone the volcanics are only represented by white saccharoid quartzites and sometimes by an arkose.

Waagen and Wynne failed to recognise the volcanic nature of some of this stage, and indeed expressed disbelief in its occurrence, as mentioned by Dr. Verchère. In a foot-note [1] referring to rocks

[1] Mem. G. S. of I., Vol. IX, 1872, Art. 3, p. 6 and p. 14.

evidently belonging to this horizon they say, "We have found no sufficient reason to suppose its breccias or other beds traceable to volcanic action, as has, perhaps, been supposed by Dr. Verchère."[1]

The position also of these beds, though provisionally assumed to be at the top of the Infra-Trias, is acknowledged by Waagen and Wynne to be equivocal, inasmuch as they may belong to the base of the Trias. I shall shew in the detailed sections of Sirban hill that their uncomformity above the Infra-Trias series necessitates their removal from that series and their incorporation with the Trias.

(2) *Upper limestones.*

Colour.

The colour of the Trias limestone is generally dark-grey, mottled with pale chrome or ochre coloured blotches. The latter are in the form of elongated oval or vermiform figures. Sometimes the colour of the limestone approaches more nearly to a deep purple with occasional bandings of deep yellow coloured courses. It is occasionally of a pale blue-grey tint when it becomes difficult to separate it from some of the limestones of the Nummulitic series. A few spheroidal ferruginous concretions, about ½ inch in diameter, are found in the Trias limestone of Wijjiyan.

Structure.

The rock is very massive and thick-bedded, but it is not so evenly bedded as the Infra-Trias. It very rarely forms dip-slopes. It weathers into much darker and more sombre colours than the Infra-Trias, which has a marked tendency to weather white or pale grey.

Minute traces of comminuted shells sometimes run in lines through the rock, but they are too much broken as a rule for identification. A minute oolitic structure is characteristic of much of the Trias limestone.

Composition.

In composition the rock is an ordinary slightly sandy limestone without any dolomitic tendency. The thick zones of massive dolomite with laminæ of

[1] Journ. As. Soc. Bengal, Vol. XXXVI, p. 29, 1867.

opaque white quartz mentioned by Waagen and Wynne [1] belong to a faulted portion of the Infra-Trias (see *infra*, page 101). A few of the beds are slightly more arenaceous than the rest, but they never become so siliceous as to merit the name of quartzites. Some steatitic clay-stones are recorded by Sub-Assistant Hira Lal from near the base of the series in the vicinity of Shakur Bandee.

Fossils of the Trias limestone.

Besides the imperfect remains of small broken shells mentioned above, there occur in certain places better preserved outlines of mollusca, which may be traced on the surface of the limestone blocks. I have found, as Waagen and Wynne found, that making any collection from this formation is impossible, owing to the way in which the fossils are "impacted in the hard rock from which they do not separate." I am, therefore, unable to add anything to what the above observers have written as regards the main Triassic limestone formation.

If reference to Waagen and Wynne's original memoir be made, it will be seen that from the occurrence of the genera *Megalodon* and *Dicerocardium* chiefly, together with *Chemnitzia*, *Gervillia*, *Rhynchonellæ*, *Terebratulæ*, and some uncharacteristic bivalves and gastropods, they regarded the formation to be a representative of the lower part of the Upper Trias of Europe and of the Para limestone of Spiti (Stoliczka). At Khaira Gali also *Ostrea Haidingeri* was identified by Dr. Waagen among the same limestone formation.

They also claim to have detected another (higher) stage of the Trias near Sulhud, in which they found the uncharacteristic genera *Nerinea*, *Neritopsis*, *Astarte*, *Opis*, *Nucula*, *Leda*, and *Ostrea*. I shall shew reason later to doubt the assigned stratigraphical position of these beds, inasmuch as a large section of the faulted Infra-Trias limestone on the north face of Sirban hill has apparently been included by Waagen and Wynne in their Trias limestone series.

[1] Mem. G. S. of I., Vol. IX, 1872, p. 6.

Some doubtful fossils.

At the base of the Trias limestone to the south-east of Bugnotur above the quartzites (1) there are some grey shales which yielded a few fossils, including fragments of a cephalopod and some bivalves, all too imperfect for identification. It is possible, however, that this horizon is lower than the *Magalodon* beds, and it may even be Permian or Carboniferous.

Dr. Verchère's observations.

Dr. Verchère writing in 1867[1] described and figured a section at the north end of the Sirban spur, that is to say across the spur E of Shakur-Bandee (see *infra*, p. 112). In this he recognised the volcanic rocks at the base of the stage; but he called the Trias limestone Carboniferous and classed it with his Weean and Kothair groups of Kashmir, the former being the zone of *Spirifer Stracheyi* and *Spirifer Keilhavii*. He also regarded certain rocks from the Niti pass containing similar fossils as of the same age. Thus although speaking of the Sirban rock as Carboniferous, he classed it correctly with groups now known to be of Triassic age.

(IV) Jurassic series.

Stratigraphical position.

The Jurassic series lies directly upon the Trias limestone in every section that has been seen of its base. Notwithstanding this, there seems to be good evidence for a slight stratigraphical break between it and the Trias, at least in certain parts of the district. Waagen and Wynne first drew attention to this in the neighbourhood of Tanakki, where the surface of the underlying limestone is eroded, overlapped by the Spiti shales (Jurassic), and pierced by the shells of boring molluscs. Further examples of this will be given in the detailed sections to follow, and it will be shewn that the bottom ferruginous layer of the Spiti shales covers the step-like outcropping edges of the Trias after the manner of a stair-carpet. In addition,

[1] Journ. As. Soc., Bengal, Vol. XXVI, p. 28, *et seq.*

evidence for discordance is afforded by the abrupt petrological change from hard compact limestone to friable shale.

Northern Section.

The Jurassics exposed in the Slate zone, and in the more northern parts of the Nummulitic zone, differ considerably from those to the south. The former comprise:—

(2) Gieumal sandstone (passage) (1) Spiti shales	}	30 to 200 feet.

The bottom bed of the Spiti shales is a layer of cystalline martite, 5 to 6 inches thick, and more or less changed to earthy and brown hæmatite and limonite. Above this the normal Spiti shales set in. They consist of jet-black or soot-black slightly micaceous shales, very fissile, and often with shining lamination surfaces.

Concretions.

Ferruginous and slightly sandy concretions run through the shales arranged in lines with the bedding. When split open they shew red, black, and yellow concentric coats. They vary in size up to a foot in diameter, and in shape from a flattened ovoid to irregular sub-angular masses. These concretions are unlike those of Spiti and Kumaun, and they have no fossil as a nucleus.

Correlation with Spiti shales of Spiti, and Central Himalaya of Garhwal and Kumaun.

By common consent these densely black and extremely fissile shales have been called after their namesake in Spiti. I have not myself seen the Spiti sections, but Mr. Griesbach named rocks of the same petrological characters and palæontological horizon in the Central Himalaya of Garhwal and Kumaun after the Spiti shales of Spiti; and having myself seen the Central Himalayan sections I can vouch for their identity of facies with my Hazara Spiti shales. There are two or three points that may be specially noted about these shales.

1. They cannot possibly be confounded anywhere with the slates of the Slate series. The latter very rarely are of such a deep black colour; and whilst they ring under the hammer and weather into a

talus of hard abrading fragments, the Spiti shales give no ring, and weather into soft paper-like laminæ, or into black clay.

2. Whilst they have such a great extension along the general strike of the Himalaya, keeping the same lithological features as far as Kumaun, a distance of about 480 miles, they rapidly change in a southerly direction (see *infra*, page 32), and are quite unknown in the Salt-Range, although rocks of Jurassic age are known through these areas. In Kashmir, rocks of Jurassic and also of Cretaceous age are unknown; doubtless they have been overlapped by the Nummulitic formation; but it is reasonable to suppose that, saving the overlap, Spiti shales of the usual character would have been found there uniting the Hazara and Spiti areas.

3. Thin friable shales occur higher up in the geological record among the Nummulitic formation, but their colour is pale grey, buff, or ochre, whilst their lamination is never so perfect.

The Spiti shales, therefore, considering their lithological characters alone, are a unique deposit, as recognisable over large areas as the Kimmeridge clay of England; but their extension is a strike extension only, with a very rapid change in the opposite direction in Hazara.

They do not appear to have been recognised by Verchère; nor is this to be wondered at, since in his section near Shakur Bandee they are hidden by gravels except up towards the higher parts of the ravine above the town.

Gieumal sandstone.

Continuing the petrological description of the northern sections of the Jurassics in Hazara, we note first a gradual passage by interbedding from the Spiti shales into the next stage, the Gieumal sandstone, which like the former takes its name from the Spiti area.

The Gieumal sandstone is an extremely characteristic rock. In colour it varies from a dark olive-green to a dark grey almost black rock, trappoid in appearance. The sandstone weathers at the surface into a brown layer, extending sometimes an inch or more into the rock. At Sha-ala-ditta the rock is banded dark reddish-brown and dark greenish-black.

In structure the rock is a close-grained, hard, and massive rock, and it frequently stands in wall-like masses. Dr. Stolickza recognised this rock as being lithologically the same as the Gieumal sandstone of Spiti, and as regards that of the Central Himalaya of Garhwal and Kumaun (Griesbach) I can myself affirm the same. Thus the distribution of this rock is co-extensive with that of the Spiti shales, above which it lies and into which it passes by gradation.

Southern Section.

One of the most remarkable features in the geology of Hazara is the sudden way in which the lithological facies of the Jurassics changes as we near the southern edge of the district. On one side of a ravine we may have the section as given before through Spiti shales and Gieumal sandstone, whilst a mile or two south on the other side of the valley the Spiti shales have vanished, only a little of the Gieumal sandstone remains—and that in one or two thin bands—whilst the bulk of the rock is made up of limestones and sandy limestones, the former ochre or chrome coloured and full of compacted shells of undeterminable species.

It is almost impossible to give a generalised section typical of this southern aspect of the Jurassics, but the following may be accepted as applicable to many localities:—

Nummulitic limestone.	
Ferruginous band (Pisolitic iron ore) . . .	1 foot.
Buff-coloured, thin-bedded shaley limestones, passing into	100 feet.
Compacted massive shelly limestone, passing into and alternating with	50 "
Alternations of Gieumal sandstone and compacted shelly limestone	60 "
Gieumal sandstone with thin calcareous beds of *Trigoniæ*	80 "
Black shaley sandstone and sometimes black shales	10-15 "
Trias limestone.	

In the Sha-ala-ditta neighbourhood there are deposits of brown rusty-coloured sandy limestones, or calcareous sandstones, which are crowded with compacted *trigoniæ*. These beds stretch away west and south-west of the Hazara boundary, and are well developed at the Margalla pass. In these southern localities, on account of the absence of the Spiti shales, it is sometimes difficult to fix the boundary between the Triassic and the Jurassic series.

For a long time I was completely baffled in trying to determine the relative position of the southern type of Jurassics as regards the northern type. It was a point left doubtful by Mr. Wynne.[1] The difficulty was that longitudinal valleys denuded along the axes of flexures shewing the northern type on one side and the southern type on the other prevailed throughout this part of Hazara. Passage sections were, however, at last found; and the general way in which the one type dovetails into the other will be best seen in the described sections (see Nummulitic zone, Chap. IV, page 177).

Palæontology of the Jurassics.

With the Spiti shales we have arrived at a great palæontological landmark. Besides their lithological identity with those of Spiti, we have sufficient fossil evidence to fix their Jurassic age beyond much doubt. Dr. Waagen[2] wrote of the Spiti shales of Chumbi peak near Changla Gali: "Here I collected—

Oppelia acucincta, Strachey.
Perisphinctes frequens, Opp. Conf. *simplex*, Sow.
Belemnites Geradi, Opp.
Inoceramus.
Cucullæa.
Pecten.

all common species of the Spiti shales." In their joint memoir Waagen and Wynne wrote: "The Spiti shales though not

[1] Rec. G. S. of I., Vol. XII, 1879, p. 125.
[2] Ditto, Vol. V, 1872, p. 17.

so rich in fossils as those of Changla Gali, yet we found in them—

Perisphinctes frequens.
Belemnites (fragments).
Inoceramus.
Corbula.

Referring to the Darwaza-Kas near Doonga Gulee, Wynne also writes[1]: "Here the Spiti shales contain—

Ammonites.
Inoceramus.
Belemnites (uncanaliculate casts).
Pecten."

In the Sha-ala-ditta neighbourhood Wynne found[2]—

Trigonia ventricosa (determined by Dr. Feistmantel).
T. Costata.

in a "marked rusty zone enclosing small grains of quartz which give a rough appearance to the surface of the rock."

Again, in the same neighbourhood he found[3]—

T. ventricosa.
Ammonites.
Gryphæa.
Belemnites.

There is sufficient evidence from the above to make a very strong case for the Jurassic age of the Spiti shales: although the fossils are not at all well preserved, nor worth collecting on their own account.

I was unable to improve upon this collection. A great many specimens were obtained chiefly by Sub-Assistant Hira Lal on the southern face of Sirban and near Changla Gali; but, beyond confirming the generalities of my predecessors, nothing more was to be made out from the poorly-preserved specimens, which need the eye of a specialist to recognise them with anything like certainty.

[1] Rec. G. S. of I., Vol. VII, 1874, p. 73.
[2] Ditto, Vol. XII, 1877, p. 129.
[3] Ditto, Vol. X, 1877, p. 125.

General petrological facies of the Jurassics.

The difference between the northern and southern types of Jurassics in Hazara seems to illustrate the difference between the Himalayan and Salt-Range types; for, whilst the northern black shales and peculiar Gieumal sandstone resemble those of the former, the southern and more calcareous elements resemble those of the latter.

Absence at Hassan Abdal.

At Hassan Abdal in the little temple-crowned hill near the town there is an absence of Jurassics altogther, and the Nummulitics with the variegated sandstone at their base cover the Trias directly.

(V.) Cretaceous.

In those parts of Hazara, *viz.* the Slate zone and the northern part of the Nummulitic zone, where the Jurassics are represented by Spiti shales and Gieumal sandstone, the latter passes up rapidly but gradually by change of material, but with no interbedding into a very thin bed, but an exceedingly characteristic one, which from fossil evidence can be definitely placed with the Middle Cretaceous (Cenomanian).

Petrology of Cretaceous band.

The rock has only one certain facies and is not more than 6 or 10 ft. thick. It is a slightly sandy limestone of bright orange or chrome-orange colour, rarely grey, as at Wijjiyan. It is fairly massive, and is dotted all over with black cherty and ferruginous patches, which in favourable localities are seen to be remnants of fossils. Occasionally these resolve themselves into remarkably good examples of *Ammonites*, and the straight and hooked forms of cephalopoda, standing out like carved figures in black relief on the hard yellow surface. They are generally more crowded together towards the upper part of the limestone band. It is almost impossible to extract them from the rock, for, like the fossils in parts of the Muschelkalk

of the Central Himalaya, only the protruding part is preserved in most cases, the remainder, fixed in the rock, shewing no structure when broken. Consequently as a rule all one could do in the way of collecting was to break away the protruding parts. At one place, however, the band had become softened into a loose sandy ferruginous marl, and in this and the surface soil above Hira Lal and myself were able to gather a rather nice suite of fossils.

I have referred above to the sudden way in which the northern type of Jurassics changes into the southern one. It is to be noticed that the Cretaceous band is only found above the Gieumal sandstone of the northern type, and that though continuous along the strike direction for immense distances—right across Hazara in fact—in the opposite direction, *i.e.*, to the south and south-south-east, it has the same limited extension that the Spiti shales have, that is to say, it is never found in the sequence above the southern type of Jurassics.

I may here mention that the black band of the Spiti shales, and the orange band of the Cretaceous, make two horizons of the greatest practical use to the field-geologist. Although the country is rarely so bare of vegetation as to shew the bed-rock when viewed from a distance, still, both palæontologically and petrologically, they are landmarks quite easy to follow in tracing out the complicated folds and inversions of the strata.

Palæontology.

Waagen and Wynne, in their Memoir on Sirban hill, speaking of the fossils of this stage say :—"They are chiefly cephalopods, with a few gastropods; one Inoceramus has also been collected. The ammonites found belong nearly all to the exclusively cretaceous groups of the Cristati and Inflati; besides this several species of Ancyloceras, Anisoceras, and Baculites appear. The Belemnites are numerous, and of rather extraordinary size for their geological age. The impression which the whole of the fossils leaves upon the observer is that of a 'Gault' fauna."

The most common form of Ammonitidæ that Hira Lal and

myself collected, fragments of which fill the rock, is most nearly allied to—

Acanthoceras mantelli, Stol.

The next most common form appears identical with—

Acanthoceras navicularis.

There are also many other allied species, all more or less related to—

A. rotomagensis.

A number of imperfect specimens belonging to the Cristati group are chiefly—

Schlœnbachia inflatus.

And a form apparently allied to—

A. blanfordianus, Stol.

All these forms are restricted to the Utatur group of the Cretaceous of Southern India, the equivalent of the Chalk-marl and U. Greensand—Cenomanian of continental geologists.

Besides the above very characteristic species a few other indeterminable ammonites and nautili were obtained.

The curved and hooked forms of cephalopoda were found in fair abundance, but generally too broken for identification; but many species appear of—

Anisoceras.
Ancyloceras.
Baculites.
Hamites?

One brachiopod, a *terebratula*, was found; and of bivalves a solitary large new species of *pholodomya.*

Of the few echinodermata collected we recognised—

Echinoconus sp.
Miciraster sp.

On the whole, therefore, I am inclined to refer the position of this limestone-bed to a horizon about that of the Utatur group or Cenomanian, rather than to the Gault; my reasons being the striking similarity of facies between these Hazara Ammonitidæ and those of Southern India belonging to the Utatur group. As the Gault follows next to the Cenomanian in descending order, the change of horizon introduced is but slight.

Similar Cretaceous rocks in the Samána country.

Whilst examining these fossils, Mr. Griesbach drew my attention to a quantity of unlabelled and unregistered fossils lying in the Museum, Calcutta, which were forwarded by Major Mainwaring from the Samána Range during the expedition of 1891 under General Lockhart. The nature of the rock and the identity of many of the *ammonites*, as well as their mode of preservation, clearly indicated the continuation of this middle Cretaceous band into the Samána country.

Rocks of Cretaceous age are unknown in Kashmir and the Salt-Range; but, considering the thinness of the band, it is possible that it may have been overlooked, especially if by chance it lost its characteristic fossils.

Possible extension upwards of the Cretaceous into what is called the Grey limestone.

A series of well-bedded grey limestones with, so far as I have seen, a complete absence of fossils, except extremely minute organisms, probably foraminifera, overlies this M. Cretaceous band. Waagen and Wynne considered it possible that it might also be Cretaceous, but gave no definite reasons. In the absence of proof I have preferred to place the grey limestone with the Tertiaries as the lowest bed of the Nummulitic series, more especially as, for reasons stated under the next heading, it is not everywhere easy to draw a line between the Grey and Nummulitic limestones, whereas the top of the orange Middle Cretaceous band is everywhere a marked feature easily seized for mapping purposes.

(VI) Nummulitic series.

This is one of the most important formations in Hazara, as it is all round the north-west frontier of India. It is of immense thickness and commands the surface over large areas in the more southern parts of Hazara almost to the exclusion of everything else. The following stages in descending order may be made in it :—

(5) Passage-beds into *Kuldana* series.

(4) Grey splintery shales and marls, interbedded with black-hearted nodular or concretionary limestone, *nummulite* bearing, about 300 ft., *Montlivaltia* zone.

(3) Well-bedded, massive beds of limestone, with *Nummulites* and other fossils generally not very concretionary, about 200 ft.

Echinolampas zone.

(2) Variegated sandstone and clays with coal, 2 to 20 ft.

(1) Grey limestone well bedded, 300—400 ft.

(*1*) *Grey limestone.*

Doubtful age.

The age of this limestone is somewhat doubtful. It is generally barren of fossils, except for a few foraminifera which are minute and obscure. They are often mere specks in the rock. It is possible, therefore, that some, if not all of it, as mentioned above, p. 38, may be of Cretaceous age. As, however, the matter is doubtful, and as stage No. 2 above is not found everywhere with ease and rapidity on the complicated hill-sides, whereas the Cretaceous orange-coloured band always stands out prominently, it has been found more convenient for mapping purposes to make the latter the line of division between the two, and to include the Grey limestone stage in the same wash of colour on the map as the known Nummulitic strata.

Petrology.

The Grey limestone, as its name signifies, is of a pale neutral grey colour, weathering white. It is very well and rather finely bedded, and of a compact amorphous structure. It weathers in a peculiar way noticeable in similar amorphous rock-masses—the surface of the blocks becomes worn down as if it had been carved with a gouge, leaving sharp meandering edges like miniature mountain ranges. I have seen the same weathering in massive rock-salt. In both cases a fall on such rocks is attended with unpleasant results.

Distribution.

Although this limestone is uniformly present in the northern part of the Nummulitic zone, and also in the outliers of the younger rocks in the Slate zone, its presence in the southern parts of the Nummulitic zone is doubtful. On the whole, I think, the evidence is chiefly in favour of its absence together with the Cretaceous band. It is also certainly absent east of Gurhee Hubeebooluh on Srikot hill. This, so far as it

goes, is another argument for placing the Grey limestone with the Cretaceous rather than with the Nummulitic. Such a conclusion would carry with it the necessity of believing in a considerable overlap of the upper part of the series beginning at stage (2).

(2) *Variegated sandstone and coal.*

This thin band of rock has already been alluded to as the direct cause of my original presence in Hazara, on account of the coal or carbonaceous clay which accompanies it.

Petrology.

In colour it is a pale French-grey, with veinings and concentric markings of pink, yellow, brown, and purple. Sometimes it weathers into a white powdery sand : at other times the rock is a somewhat coarse-grained grit and weathers into irregular lumps which are fairly hard under the hammer. A sugary texture is characteristic. What is apparently the same rock on Srikot hill east of Gurhee Hubeebooluh, and forms the base of the Nummulitic series there, is conglomeratic in its lower part where it rests upon Infra-Trias limestone.

In the southern parts of Hazara, and on its borders in that direction, as at Hassan Abdal, the variegated sandstone is underlaid by a coarsely pisolitic ferruginous band. In the event of the Grey limestone being Cretaceous the above pisolitic band would very reasonably represent the similar rock at the base of the Nummulitic series at Sabathu and in western British Garhwal.

Coal and carbonaceous clay.

In certain places in the Slate zone this variegated sandstone contains a band of carbonaceous clay containing coal. Owing to the softness of this rock and its enclosing sandstone, as compared with the great limestone series above and below it, we find the coal and clay have become crushed and sheared, one might almost say kneaded together, so that although the richer carbonaceous bands may have been formed originally in a continuous bed, they are now unrecognisable as bands, except locally, the richer and poorer material

having been squeezed the one into the other. For the same reason the thickness of the carbonaceous band varies greatly. In very many places and over wide areas it is not known to exist at all, so far as the surface outcrops can tell us anything, although the variegated sandstone band is present. In other places a mere smudge of carbonaceous material on the hill-side has led to its being found some few yards into the hill in a bed of several feet thickness. The thickest known section is at Begarmal on the ridge south-east of Juswal, where 17 feet of coal and carbonaceous clay have been exposed.

In the appendix, p. 288, I give further details about the coal considered from an economic point of view.

As regards its horizon, I have little doubt that it is homotaxial with the coal of the Salt-Range, which is also found at the base of the Nummulitic limestone.

(3) *Well-bedded massive Nummulitic limestone.*

This rock is always slightly concretionary, generally black-hearted and of fœtid smell when freshly broken. It weathers into dark grey or pale grey colours at the surface. *Nummulites* and other foraminifera, generally of very small dimensions, not exceeding that of a grain of oats or barley, may be seen in the rock in swarms or colonies, and generally following round the imperfectly-formed concretions. Along the southern edge of Hazara this limestone is more markedly concretionary, and more nearly approaches in appearance that of the Salt-Range.

Petrology.

The hill near Hassan Abdal, though outside the district of Hazara, is interesting for the occurrence of a zone of *Echinolampas* sp., the fossils being very numerous in a layer 3 feet thick coming above the variegated sandstone stage; and with a bed 10 feet thick between them of thin-bedded limestones, marls, and shales of an ochre colour and full of gastropods and bivalves.

Echinolampas zone.

(4) *Shales, marls, and concretionary and nodular limestone.*

This upper part of the great Nummulitic formation is very distinctly more shaley as a whole than the lower part, whilst the

limestones which are interbedded, though varying considerably in different localities, are, as a whole, in comparatively thin layers. Where very thin they are nodular rather than concretionary, the nodules being very nearly though not quite separated from the matrix. They are generally about the size and shape of a hand with fingers closed.

The shales and marls are exceedingly splintery, and vary in colour from a pale grey or drab to a pale greenish-grey and sometimes to a dark grey. However dark they may become they never approach the deep soot-black of the Spiti shales, whilst their tendency to splinter rather than to split into laminæ further distinguishes them.

These upper shales, marls, and nodular limestones are much more fossiliferous than the lower beds. The *Nummulites* are much larger. In spite of this the compacted nature of the limestone, and the splintery and crumbling nature of the shales and marls, make collecting from the rock unprofitable.

A band of corals, *Montlivaltia* sp., in great numbers and very well preserved, occurs as an exception to this on the southern craggy face of Sirban hill just above the village of Nugukkee.

(VII) Kuldana series (Passage beds).

Sometimes enfolded among the Nummulitic limestone in very narrow bands, and sometimes lying beneath the Murree beds (see *infra*, p. 43), there are a set of intermediate deposits of no very great thickness which bridge over or connect the two series. These deposits have been called the Kuldana beds, and although of minor importance, since they have an individuality of their own, I have thought it best to retain the name and to use a separate colour for them on the map.

Petrology.

They consist of shales, clays, marls with calcite veins, and fine sandstone. The prevailing colour is deep inky purple or sometimes chocolate-brown. There are also subsidiary greenish and olive tints. The prevailing brown or purple is a noticeable feature in the landscape, as they stain whole hill-sides with their dark reddish débris.

Composition.

The shales or hardened clays and associated sandstone beds are thin-bedded and very gypsiferous in places. The gypsum is bedded or banded white and grey, as near Clifden. In other places a rotten yellow hardened marl or calcareous clay is invaded by a mesh-work of fine calcite veins. Pale lavender coloured calcareous shales are also invaded in the same way.

The purple sandstones and calcareous sandstones associated with these rocks are very frequently full of *Nummulites*, and they pass up into purple sandstones and into dark or light purplish and green sandstones of Murree type. Along with these go very fine pseudo-conglomerates or clay-conglomerates of similar colours. There are a few earthy concretions in the purple shales.

Beyond *Nummulites* and a few badly-preserved bivalves in the more calcareous layers, there is nothing to be noticed palæontologically about the beds.

(VIII) Murree beds.

This great formation is not present to any extent within the boundaries of Hazara. In the neighbourhood of Murree, however, and along the south edge of the district, it appears in narrow width, whilst away to the south across the great Rawalpindi plateau, it and the younger Siwaliks cover an immense area.

It is not necessary, therefore, to describe it minutely, more especially as Mr. Wynne[1] and Mr. Medlicott[2] have already mapped and described it pretty thoroughly.

Petrology.

It is generally a very fairly micaceous rather soft sandstone of pale bluish-green and pale purple colours, mixed in a pepper and salt way, so as to catch the light in varying proportions according to the position of a freshly-broken surface. The rock weathers to a pale or dark greenish-grey or brown.

[1] Note on the Tertiary and underlying rocks in the north-western Punjab. Rec. G. S. of I., Vol. X, pt. 3, 1877.

[2] Note on the Sub-Himalayan series in the Jamu hills. Rec. G. S. of I., Vol. IX., pt. 2, 1876.

With the sandstone, which is the most prominent member, there occur beds of deep purple shales or clays, also pseudo- or clay-conglomerates, as in the Kuldana beds into which they pass.

It will be readily seen that we have in Hazara just the outer fringe of this great member of a mighty formation.

(IX) Recent.

So far as is known to me there are no rocks of Siwalik age in Hazara. None of the valleys or plains anywhere exhibit an older set of compacted and disturbed conglomerates or other deposits unconformably covered by the modern alluvium and gravel terraces.

No Pliocene in Hazara.

The latter, however, are a very marked feature in Hazara, inasmuch as they fill broad valleys, such as the Hureepoor plain, the Dore valley, the Abbottabad plain, the Mansehruh plain, etc., not with a thin light covering, but to a depth which must often exceed 300 feet. Besides being found in the larger valleys and plains, the same gravels can be followed for long distances up the main rivers, such as the Dore and the Haro rivers and their tributaries. In such places they are often a mere remnant, left plastered as it were at different heights on the slopes above the present drainage, or sticking out bracket-wise at intervals from ravine sides, and planted with villages. These small continuations of the gravels could not be represented on the map without giving it a patchy appearance and interfering with the delineation of the solid geology; but the reader must be pleased to understand that all the stream-beds and gorges, besides being filled with stones along their actual beds, possess high-level gravels up to a certain height and in varying proportions. Near Ghazi, on the Indus, the height of the gravel plateau above sea-level is 1,100 feet, near Turbela it is from 1,200 to 1,500 feet, at Hureepoor 1,600 feet, at Sooltanpoor, on the Dore, 2,800 feet, at Rujoeeuh about 3,000 feet, at Nuwanshuhr 3,900 feet, at Abbottabad 4,100 feet, at Mansehruh 3,000 feet, and so on. The larger plains lie generally at different heights

Alluvium and gravels.

between 1,000 and 4,000 feet; but up the smaller rivers and their tributary gorges the recent gravels may extend 1,000 feet higher.

It should be noticed that between the 1,000 feet level of the gravel terraces at Turbela and the 4,000 feet level of Abbottabad there is a *gradual* ascent along the Dore as far as Dhumtour, and then by the Jub. N. to Abbottabad. The average gradient of this slope between Turbela and Hureepoor is 1 in 132, between Hureepoor and Sooltanpoor 1 in 66, between Sooltanpoor and Abbottabad 1 in 59 (taken along the Dore and Jub. N.) and 1 in 30 (taken along the Sulhud N.). The Recent deposits of Hazara are in fact all linked together, and their levels, along any river course from below upwards, or from a larger river up gradually diminishing tributary streams and torrents, may be represented by a curve, convex towards the sky, and of increasing steepness towards the higher levels. Such an arrangement is in accordance with normal fluviatile deposition, and no lake basins are required to explain such recent deposits of gravel and alluvium.

Glacial moraines.

The only old moraine (indicating the agency of ice), that I have seen in the lower parts of Hazara occurs at a level of about 6,000 feet at Gool Maira, in the Koonhar valley. Doubtless many occur above this up the valleys leading down from Khagan, but I have not visited them.

Erratics.

The subject of "erratics" in the Punjab provoked a little word-fencing between Mr. Wynne and Mr. Theobald (see papers in list of authors, page 7) about 15 years ago. Whilst Mr. Wynne named as erratic any displaced mass or boulder of foreign rocks whose means of transit appeared abnormal, Mr. Theobald confined the term to rocks in such positions as would entitle them *a priori* to a glacial origin, or at least to having been transported by ice in some form. In his paper on the occurrence of erratics in the Potwar,[1] *i.e.* the plain south of Hazara bordering the Indus and Sohan rivers up to the Salt-Range, Mr. Theobald describes a number of huge blocks of crystalline granitoid gneiss, scattered about and imbedded in thin silt mostly near Jhand;

[1] Rec. G. S. of I., Vol. X, pt. 3, 1877.

whilst others were described by Major Vicary[1] between Hassan Abdal and Attock. Mr. Wynne has remarked on others in the bed of the Indus near Turbela and along the Sirun river (Hazara). Those on the Sirun and Indus rivers I shall shew later on to be by no means displaced blocks, but to be actual outcrops (or quite close to actual outcrops) of the gneissose-granite of Hazara. As regards those of the Potwar, having never seen them, I am, perhaps, hardly entitled to an opinion; so I will merely content myself by drawing attention to the fact insisted on by Theobald regarding the Jhand erratics—that they occur in lines running E.N.E. and W.S.W. He interprets this as due to disposition by ice; but I would ask why, considering this is the normal strike of the country, they should not be similarly due to blocks weathered out nearly *in situ* from a ridge of crystalline rocks covered sparingly by, or protruding through, the Upper Tertiary sandstones?

As regards the erratics mentioned by Wynne south of the Salt-Range, I think there can be no doubt that they were derived from the Salt-Range boulder-bed, whence they have simply subsided down hill.

Having seen a good deal of glaciers and ice work in the higher Himalaya, and having likewise worked over the Sub-Himalaya and Outer Himalaya through a large tract, I am bound to say that no reliable traces of glaciers at low levels (say below 5,000 or 6,000 feet) have ever come before my notice.

I regret very much that I never saw the Potwar erratics (so called) and I would commend the study of them from the standpoint I have indicated to any future geologist who is in the neighbourhood.

CRYSTALLINE AND METAMORPHIC ROCKS.

General Remarks.

Occur in the northern parts of Hazara.

The northern half of Hazara, the wild glens of the Black Mountain, and apparently most of the little-known country which stretches away further to the north into the higher snow-clad ranges of the Hindu-

[1] Quart. Journ. Geol. Soc., Lond., Vol. VII, 1851.

Kush proper, possess a marked uniformity of composition and structure, consisting as they do of a great complex of gneissose and schistose rocks interwoven the one with the other, and laid out in parallel flexure waves one behind the other.

Of great interest as being a continuation of the Himalayan crystalline rocks.

The geological and physical problems which arise from a study of the above are of great interest and importance, when we consider that both as a first impression, and as a matured belief based on years of study of them in the field, it appears evident that this great complex is a continuation of the similar crystalline and more or less metamorphosed rocks of Kashmir, also of those of other parts of the Himalaya which have been partly described geologically and some of which are personally known to me, *viz.*, the Dalhousie, Chamba, and Simla neighbourhoods, and parts of Tiri and British Garhwal and Kumaun. For, as regards the nature, origin, and age of these rocks, whatever can be proved true of them here, must in all reasonable probability apply equally along the length of the great crystalline backbone of the Himalaya and Hindu-Kush.

Questions needing answering.

With the above far-reaching implications in view, and knowing well what opposite opinions had from time to time been expressed by geological observers engaged at different parts of these areas, I entered on the examination of these rocks with the following questions or possibilities constantly before me (neglecting for the present other minor questions and side issues) :—

(1) Is there evidence in this great crystalline backbone for anything of the nature of an archæan series?

(2) Do any of the gneissose rocks represent foliated or rolled out granites or allied rocks that have come into their present axial position in the great ranges by an intrusive process?

(3) In the latter eventuality what was the date of that intrusion?

(4) Are the crystalline schists, which are found associated with the gneissose rocks, truly metamorphosed sedimentary deposits, and if so, what was their original age when laid down as sediment?

(5) If the first part of (4) is answered in the affirmative, what was the date of the metamorphism affecting them, and was it or was it not caused by the intrusion of the gneissose-granite, assuming the existence of the latter?

Mr. Wynne's references to these rocks.

Mr. Wynne's references to these rocks are mainly restricted to two of his papers, in the latter of which (without sufficient cause in my opinion) he comes to an opposite conclusion to the one arrived at in the former.

In 1877[1] he describes them under two headings, (1) crystalline, (2) metamorphic. The former he describes from the Pakli Valley, Susalgali, etc., as "Syenitic rocks, granitoid porphyry, and greenstones." The granitoid or granitic porphyry, he adds, is exactly like that occurring in erratic masses near Nowshera in the Jhelum Valley, presumably derived from the Kajnag range, etc.; and he also mentions in a foot-note that Dr. Stoliczka recognised a block of it occurring in the Jhelum at Hutti Kashmir as being similar to his so-called albite-granite.

The latter (metamorphics) he (Wynne) describes as slightly metamorphosed, dull, talcose, silky slates, lying outside the Hazara granitoid rocks, and which he believes to represent the Attock slates. He also mentions greenstone dykes intersecting the slates, and syenitic protrusions; but he adds that no stratified or foliated gneiss nor any mass of quartzites or mica schists were met with by him, though such were known (he remarks) to Dr. Fleming. He also mentions crystalline marble and sub-crystalline compact to pseudo-brecciated limestone of the Gundgurh range as occurring among the slates. He found no fossils in these metamorphic limestones, but near Dakner he records "obscure traces," and further west at the Mirkulan pass, he says, a few fossils can be distinguished (but see *ante*, page 13).

In the second paper of later date[2] Mr. Wynne speaks in a more guarded way of the "granitoid gneiss of Hazara," and no longer refers to granitoid porphyry or syenite. He is inclined to think there

[1] Rec. G. S. of I., Vol. X, p. 113.
[2] Rec. G. S. of I., Vol. XII, p. 116.

is an ascending series from the slates to the Hazara "gneiss," among which traces of inter-stratification are apparent. As regards the metamorphism of the slates, etc., up to the gneiss, he remarks on it exhibiting a lateral or geographical development rather than a development coinciding with the antiquity of the strata. He again mentions the lithological identity between the gneiss of Hazara and that of the Kajnag range. He now defines the gneiss as a completely crystalline granitoid rock composed of quartz, felspar, and black mica, white mica being often present, with porphyritic crystals of felspar lying sometimes parallel and sometimes at random in it, and with schorl and garnets locally present. He then makes some noteworthy remarks about the habit and lie of the gneiss. Although he sometimes obtained what appeared to be dykes of it cutting through the schistose rocks, he also sometimes found what appeared to be a gradual transition from the schistose rocks to the granitoid mass, the actual contact being, however, defined within rather narrow limits. He remarks also on the inclusions in the gneiss of portions of schists at Susalgali pass in Agror, where the included fragments are sometimes much changed and almost as much crystalline as the including gneiss, and those of Mansehruh in which the inclusions are often completely unchanged.

Mr. Wynne then sums up this somewhat conflicting evidence by saying (page 119) that "the whole aspect of the gneissic or granitoid region gives the impression that an extensive series of mechanically formed detrital rocks has undergone transformation, the metamorphism being locally intense, *and its extreme results expressed by a very abrupt transition from highly altered schists into the gneiss itself.*" I can scarcely think, however, that the words italicised by me above convey a legitimate conclusion from the facts recorded.

Regarding the "less highly altered azoic rocks" he says the metamorphism of the schists bears a more or less constant relation of place to the margin of the gneissic tract, though it possesses no definite outer boundary. He makes a very suggestive remark relative to the metamorphism of the schists on the Hazara

bank of the Indus, which metamorphism traverses across the strike of the beds obliquely "as though it were an effect related to the presence of the gneiss among the Buneyr hills in the wild tract beyond that river, or to *other plutonic rocks* beneath the region." Here again the facts, as detailed by Mr. Wynne, seem to make dead against the theory of the gneiss of Hazara being an extreme case of the metamorphism affecting the schists acting on an ordinary detrital rock. The words "*other plutonic rocks*" italicised above seem to suggest even a confusion in his own mind.

With regard to the basic rocks intrusive in the region, Mr. Wynne mentions them as occurring in the more or less altered metamorphic rocks and also in the Tanol group. One intrusive mass of large size he describes south of Bahingra mountain. He speaks of them as dense dark greenstone, and gives no further details of their constitution.

In subsequent papers by the same author the only references made to the gneiss are by way of correlating it with the Kashmir gneiss, and he seems to have made up his mind as to its being an extreme product of the metamorphism of previously sedimentary beds.

Dr. Albert Verchère's remarks on this rock.

Dr. A. Verchère,[1] speaking of the "porphyry" of the Kajnag range, Kashmir, by which he means the rock now known as gneisose-granite, remarks that he had had described to him some granite seen a few miles from Mansehruh near the entrance into the Khagan valley which appeared to be a volcanic porphyry similar to that of Kashmir. Although he fell into the error of calling the porphyritie orthoclase crystals, albite (and possibly in calling the schorl augite), he nevertheless recognised the correct interpretation of it as a foliated igneous rock, and not a metamorphic sedimentary rock, as is evident from his remark.—"It very often happens that the minerals are arranged in bands or layers as in gneiss, and this apparent foliation also varies much and often it does not exist at all, whilst in other instances it is

[1] Journ. As. Soc. Bengal, Vol. XXXV, p. 108, 1866.

extremely well marked, thus gradually forming a passage to the clink stone described," etc., etc.

Turning now to the evidence which I shall myself offer regarding this crystalline complex, it must be understood that the general results of petrological research, no less than the special knowledge gained since Mr. Wynne's day in other parts of the Himalaya, prepared me for finding much, if not all, of this gneissose rock to be a granite which has undergone a subsequent foliation. Although I hope to present clear proof of this in the course of this and subsequent chapters, sufficient at least to evade the charge of putting new wine into old bottles, yet in the main my observations agree with Wynne's, and my task is rather that of applying a more modern interpretation to those observations, and one which I have little doubt Mr. Wynne would have himself applied had he been working there with our present knowledge.

My own evidence.

The following rough grouping of these rocks is adopted for simplifying the description of them :—

(1) Slightly schistose rocks, the metamorphic representatives of the Slate series.

(2) Slightly schistose rocks, the metamorphic representatives of the Infra-Trias.

(3) More intensely metamorphic rocks, presumably representatives of the Slate series in the main.

(4) Bands of gneissose-granite intrusive among (1) and (3).

(5) Trap dykes-intrusive among (1), (2), (3), and (4).

(6) Appendix on the river-boulders brought down by the Indus river from unknown country to the north.

(1) *Slightly schistose rocks, the metamorphic representatives of the Slate series.*

Immediately north of the so-called Slate zone near Mansehruh one may see plenty of good examples of this group and chiefly of an arenaceous type. Their metamorphism has not gone very far, and the first results on the rock have been to give it a rotten

disintegrated appearance. The new forces, which have come into play as part of the metamorphism, have not gone sufficiently far to give the rock a thoroughly crystalline structure, whereas they have gone far enough to destroy the previous coherence of the rock along its original planes of bedding. As a consequence of this, the great expanse of slightly schistose rocks, which forms much of the country around Mansehruh, is in a rapid state of disintegration by weathering and river action: the rock powders up at the surface into a soft micaceous sand which can be dug with a spade.

Arenaceous schists.

Under this heading I include a great many pale-grey or brownish fine-grained sandy rocks, which shew every indication of having been originally formed as ordinary sediment. In most cases the original planes of bedding are quite discernible, being indeed more easily detected than the subsequently induced foliation. The angle between the planes of foliation and the bedding planes are quite irregular; the one may be nearly coincident with the other, or it may be (as in a specimen ¾ mile north-east of Mansehruh) exactly at right angles to it. The above specimen shews a perfect banding of differently coloured sedimentary material, the bands running in sharp straight lines just as the bedding planes do in a fine grit. False-bedding on a fine scale is also discernible. The foliation planes, on the other hand, cut across these at right angles and undulate gently. The rock tends to break along the latter, revealing feebly glistening surfaces of mica.

A specimen of mica-schist taken ½ mile north-east of Mansehruh, No. $\frac{9}{513}$ [1], shews, under the microscope and also in the hand specimen, a very marked instance of what I have called elsewhere lenticular-tabular foliation on a fine scale. The quartz-grains have become elongated or rolled out under pressure into lens-shaped bodies or minute eyes connected one with another. Between the waving layers development of mica has gone on to a considerable extent. The magnetite in many places has been drawn out parallel to the

[1] The numbers here and elsewhere are the numbers of the specimens given in the Geological Survey Rock Register.

eyes of quartz. Under crossed nicols the slice shews plain evidence of crushing and the formation of mylonitic structure. This specimen was taken close to a band of gneissose-granite.

Other arenaceous rocks belonging to this category are more of the nature of glassy quartzites.

Phyllites.

In contrast to the more arenaceous type of schistose rock just described come the silky-surfaced argillaceous schists or phyllites. In the neighbourhood of Mansehruh they are not prominently noticeable, but in the Gundgurh range they are a marked feature. The northern part of that range, stretching from near Turbela to the south-west confines of Hazara, is composed of a great expanse of rocks, which are transitional between the normal slates of the Slate zone and the more perfect crystalline schists to be afterwards described. One of the first features indicating the beginning of a metamorphic condition is the presence of vein-quartz ramifying through the rocks. A noticeable instance of this occurs near Sobruh Gulee, where the very slight alteration that the slates have undergone would be scarcely appreciated were not the attention drawn to it by the numerous veins of quartz.

Interbedding of the arenaceous and argillaceous types.

The arenaceous type and the argillaceous type of faintly schistose rocks are often observed interbedded together. In the Gundgurh range, and also near Seree-Sher-Shah on the Sirun river, examples may be found in which incipient lines of foliation cut through the rock and cross at an oblique angle the interbedded, more sandy, and less sandy layers.

Graphitic schists.

Along with the phyllites in the Gundgurh range and Tanawal come graphitic schists, which are a very noticeable feature in the landscape, owing to the black carbonaceous dust into which they weather, darkening the hill-sides round about. The bands generally, as in the Gundgurh range, are from 10 to 30 feet thick, but very impure. They are much crushed and contorted with quartz veins and iron staining. In the Black Mountain a similar band of graphitic schist gave only a small percentage of carbon when analysed in the Survey laboratory.

Crystalline limestone, marble, etc.

I have already described some thin interbedded limestones as occurring in the Slate series, *e.g.*, the Lungurial band, etc. As a parallel case there occur similar bands of partly metamorphosed limestone among the slightly schistose slates of the Gundgurh range, Tanawal, etc. Near Chooean and Budda along the backbone of that range there are limestones which it is almost impossible to classify as belonging to the Slate series or to the metamorphics. They still retain their dark grey colours and cryptocrystalline structure, but they have become banded with paler-tinted layers, and they split along certain directions displaying a semi-schistosity of the same nature as the associated slightly schistose slates. Some of them again in the neighbourhood of trap-dykes, apparently intruded along the bedding, have become blotched and traversed by calcite in patches and veins. Some again Wynne has described as "puckered" and "frilled," a condition very much resembling that of a contorted mica-schist. Near Budda, and also near Bataura, $\frac{9}{527}$, there is a band of white marble, and at Lalo Gulee grey and ochre banded marble occurs among the schists.

Metamorphism of the above rocks as a whole.

Whether taken as a whole or individually the above examples are perhaps sufficiently illustrative of the slightly schistose representatives of the Slate series as they occur along the south portions of the great schistose and gneissose area. The appearance in the field, as well as the study of the hand specimens, force the only conclusion possible, namely, that these incipiently schistose rocks are altered sediments of the same general composition as those forming the Slate series. Furthermore, the fact that a gradual transition from the one to the other takes place along the long axis of the Gundgurh range may be considered proof positive of the above conclusion.

(2) *Slightly schistose representatives of the Infra-Trias.*

If further proof were still wanting that the slightly metamorphic sub-zone of rocks to the south of the main crystalline masses are

genuinely altered sedimentary rocks, it may be found in the examples which I shall now give of metamorphosed rocks belonging to the Infra-Trias.

Schistose conglomerate.

At several places along the Tanawal country there are examples of a conglomerate shewing all stages of development from the normal Infra-Trias basal conglomerate such as we have seen near Tanakki up to one in which nearly all the constituent pebbles have been deformed, flattened, and dragged out into flakes, whilst the intervening matrix has become a distinctly schistose rock. One of the first stages is to be found near Sobruh Gulee, where the conglomerate has been cleaved and the pebbles turned round in their soft matrix, their long axes being arranged at a considerable angle with their original bedding planes. The pebbles when extracted shew some of the matrix adhering to their ends and are in consequence lens-shaped, whilst what was originally a fine-grained enveloping shale interbedded with and surrounding the pebbles has become a cleaved slate.

A more advanced form of cleaving with distortion of the pebbles is seen on the road from Chumhud to Nukkeh, and a still more advanced stage north-east of Chountree near Srikot in the Gundgurh range. In the latter the flakes which now represent the original pebbles are so drawn out, flattened, and cut through by parallel shear planes, along which incipient metamorphism has begun, that it is difficult to trace out the original boundaries of the pebbles.

Metamorphosed purple slate, Infra-Trias.

In certain places, as at the ziarat ½ mile east of Kurm, the representative of the purple shales which succeed the conglomerate has become a sheeny-surfaced schistose slate, extremely fissile, the surfaces being covered with minute specks or raised blisters (incipient garnets?).

Metamorphosed Infra-Trias limestone and quartzite.

Still ascending in the Infra-Trias series we may now notice the limestones and quartzites, which, though quite recognisable petrologically, and by their stratigraphical relations to the preceding stages, have become considerably metamorphosed along the length of these

their northern exposures in the Tanawal country. The general nature of the metamorphic change in the calcareous members of the series is that what was previously a sub-crystalline or crypto-crystalline rock has now become obviously crystalline to the eye, though except in a few cases the limestone has not become marble. In colours they vary from pale drab to white, veined with grey and enclosing a bright green mineral. Some purple calcareous shales near Kurm have a schistosity developed in them, with slightly curled or wavy surfaces filmed with mica. They correspond faithfully to the similar unmetamorphosed rocks of Sirban hill. The peculiar mode of jointing and weathering of the Infra-Trias limestone, referred to in an earlier chapter, are also characteristic of many of the more northern metamorphosed varieties.

Of metamorphosed quartzites (or quartz-schists as they had better be called) belonging to this series, there are great thicknesses exposed in Tanawal and the Gundgurh range. Their exact relations to the limestones is not quite clear, but it seems certain that they are not all confined to a position beneath the limestones, and that they therefore represent an arenaceous type of deposit which probably alternated with the calcareous beds along this line of country. It was chiefly owing to the difficulty Wynne found in separating these along their northern boundary from the older schistose representatives of the Slate series that made him hesitate at first to call them and the limestones Infra-Trias, and instead to invent the special name of "Tanols" for them. I have found the difficulty to be equally great, especially for the purposes of close mapping, and so have retained the name "Tanol quartzites" for these somewhat remarkable rocks. I shall have to refer again to this point when the stratigraphical relations of the sections in different zones and areas are described (see Chap. VI, p. 237). For the present I must return to the petrological description of them.

Most of them to the north of Sobruh Gulee in the neighbourhood of Bilihana mountain shew lenticular-tabular foliation to a very advanced degree. Wherever a coarser grain of quartz occurs in the rock it

has been powdered and drawn out into an eye, and wherever pebbles occur the same distortion has happened to them, or they appear first to have suffered a slipping of one part over the other. The above is what may be seen with the eye on every foot of exposed rock on the hill-side. With the aid of microscope slides the same distinctive features can be more clearly made out. A specimen ½ mile west of the "S" of Sobruh Gulee in addition to shewing the above mylonitic structure has the quartz grains in many places completely, and in others marginally, altered into a polysynthetic aggregate comparable to those figured by McMahon (Min. Mag., Vol. VIII, Pl. II) in the quartz of the quartz-felsite of Tusham hill. Another specimen of quartz-schist ¼ mile north of Teer village, $\frac{9}{558}$, possesses a slightly mylonitic structure visible with the microscope, undulose extinction of the quartz grains, and white mica waving round the latter. A pale grey quartzite from near Ghazi north of the Gundgurh range, $\frac{9}{557}$, is an ordinary quartzite with a few grains of microcline and triclinic felspar.

(3) *More intensely metamorphosed rocks, presumably representatives of the Slate series in the main.*

Having seen that so far as the southern margin of the great crystalline and metamorphic area is concerned, the rocks shew many stages of incipient metamorphism and that they can be individually recognised as being altered lower members of the normal historical sequence of formations described in the earlier portions of this chapter, it will now be my object to take for description examples of the more thoroughly crystalline foliated rocks such as are found only in the more northern parts of the district, namely, Agror, Khagan, and the Black Mountain. Among these strata the metamorphism is so complete that there is no longer any direct evidence from individual samples and sections that the rocks are true representatives of what were originally sedimentary deposits. The only reasons for supposing them to be such are of an indirect nature, though very strong. Briefly stated, the reasons above all others for the above supposition are (1) that it is impossible to draw any hard-and-fast line

between the more metamorphosed and the less metamorphosed: the two extremes of type grade into one another by many a passage form; and (2) the agent by which the metamorphism has been produced (as will be afterwards shewn), namely, the intrusive gneissose-granite, continues of the same general composition, structure, and habit through the whole breadth of the metamorphosed strata, being found alike among the slightly altered arenaceous schists of Mansehruh and the well-foliated examples now to be described.

Junction of Shál N. with Indus river, Black Mountain.

Mica-schist from the locality marginally-noted No. $\frac{8}{883}$ appears in the hand-specimen as a beautiful thoroughly-well foliated schist, the pale mica being very prominent on the foliation planes. Black mica can also be discerned in small quantity.

Under the microscope the structure is seen to be that of a typical mica-schist. The layers of granular quartz, pale and brown mica, lie in almost perfect parallelism. Besides the above minerals, there are very minute irregular isotropic bodies with a high refractive index which are most probably garnets. There is no mylonitic structure visible, and whatever crushing the rock sustained originally has been entirely masked by the thorough re-crystallization of the mass. No trace of an ultimate clastic origin can be detected.

50 yards east of above locality.

A slightly garnitiferous mica-schist from 50 yards east of the last locality, No. $\frac{8}{884}$, is of a darker colour, due to the larger proportion of black mica contained in it. Like it, however, it is a thoroughly crystalline schist devoid of crumpling or corrugation and the folia perfectly parallel. A small amount of felspar is noticeable. The microscope confirms the above. White mica is seen to be completely absent. The garnets are larger than in $\frac{8}{883}$ and shew ragged outlines and evidence of crushing or else of imperfect development. The plates of brown mica wave round the garnets in places. There are a very few examples of felspars also with ragged outline, some shewing binary twins. All the flespars are crowded with minute needle-like inclu-

sions, a characteristic which the felspar always possesses when present in these schists.

There is no suggestion, in spite of the occasional felspars, that the rock is an ultimate stage of the pressure metamorphism of a granitic rock. On the contrary it seems very much more probable that the felspars have been produced in the schist by the proximity to it of a band of gneissose-granite. Further examples will abundantly illustrate this. Dr. A. Lawson (Rainy Lake Geology, Annual Report, Canadian Survey, 1887, p. 33 F) describes a similar case in reference to the schists in contact with the Laurentian gneiss which has acted as a granite in places. He writes: "Within the hornblende-schists, distinctly recognisable as such, there may occasionally be detected large crystals of felspar which are quite foreign to these rocks; as if the felspathic magmas had penetrated within the schists and crystallised there in the same large crystals in which they are wont to appear in the coarse gneiss."

This feature is only noticeable here on a small scale; but in the neighbourhood of Kedarnath in British Garhwal I have seen very much more pronounced effects of the same kind.

Another rock from the same locality.

In a similar rock from the same locality, No. $\frac{8}{885}$, the presence of felspars is distinctly visible to the eye. Under the microscope they come out more prominently in generally irregularly elongated grains shewing binary twins. The minerals composing the rock are the same as in the last specimen. The inclusions in the felspar are also the same as in that rock, though there are also included fragmentary rounded little beads of garnet. The larger garnets which enter into the composition of the rock are in sub-angular idiomorphic grains, much cut through by irregular dark cracks, and almost colourless or of a very pale port-wine colour. The minute beads of garnets included in the felspars seem to be in some way connected with the large grains which are always near to them, as if the one had given up its material to form inclusions of a secondary nature in the felspars. The brown mica of the rock bends round the felspar grains.

The development of the felspar and garnets in the mica-schist of this locality is evidently connected with the proximity of several veins of gneissose-granite which run among the schist generally parallel to the foliation.

Right bank of Indus river, W. of Ghazikot.

No. $\frac{8}{889}$ is a highly foliated mica-schist from the locality marginally noted. It is more coarsely crystalline than the preceding examples, and the foliation planes are sharply defined and straight. It is composed of quartz in abundance, white mica, and a little brown mica. Glass and fluid inclusions are present in the quartz.

½ mile N. of Kotkai.

No. $\frac{8}{896}$ is selected as an example of the more arenaceous type of well-crystallised schist. The rock has been completely re-crystallised. There is no trace of any original sedimentary condition left either in the form of bedding or banding or of manifestly fragmentary material. In minute quantity dispersed through the rock occur brown mica and white mica in minute patches and shreds, and garnets as in the last specimens. The spaces between the individual quartz grains are filled up by secondary silica or by shreds of mica, brown and white.

Garnitiferous schists.

Examples of schists in which the garnets are more numerously developed, sufficiently for the rock to be called a garnitiferous schist, are known in many places, *e.g.*, ridge north of Diliari overlooking Dedal, above Kunhar on the Indus river, and north-east of Abu (all in the Black Mountain). Sometimes the garnets occur gathered together into nests about ½ inch across, and sometimes the rock is almost full of a small variety about the size of a pea.

Hornblende schist.

Of hornblende-schists there is a complete absence in the parts of the Black Mountain and Hazara to which I have had access. There are abundance of foliated traps which in some respects mimic hornblende-schists, but there are none of those well-crystallised hornblende-schists of which the origin is at least doubtful. Nevertheless, from the presence of boulders of them in the river-bed of the Indus river near Lalo Gulee

it is reasonable to conclude that rocks of that nature must occur *in situ* somewhere higher up the Indus valley in the direction of the Chagarzai country and Swat.

Even these rocks, Mr. Holland thinks, owe the hornblende to uralitic changes of augite.

Chloritic schists.

Of chloritic schists I have one example as a band in the gneissose-granite a little north of Mansehruh. It occurs in lenticular layers, through the well-foliated matrix of which there are scattered fairly large porphyritic felspar crystals. The appearance of this band and others in the vicinity dipping in a wavy and puckered way with the foliation of the gneissose-granite is as though the matrix of the latter had changed into the soft chloritic schist, the porphyritic felspars remaining the same.

Talcose and Steatitic schists.

Of schists of a faintly talcose character there is doubtless a wide distribution in these parts, but in the field it is not easy to work out their boundaries and separate the faintly micaceous schists.

About ¼ mile south-east of 5,202 feet hill near Burkot in Tanawal the metamorphosed Infra-Trias had been excavated in a small way for steatite, and the finely fissile rock evidently contained a fair proportion of the mineral, but in only a rather thin band of a few feet in thickness.

(*4*) *Bands of gneissose-granite intrusive among* (*1*) *and* (*3*).

General characters.

We will now turn our attention to the gneissose-granite which is present in the form of intrusive bands among the schistose rocks. These bands are generally parallel to the foliation of the rocks among which they lie, and they vary in thickness within very wide limits: a band may be as much as 4 or 5 miles broad with scarcely any interruption, except trap-dykes, or it may be merely the thickness of a finger or even less (as in the cases already briefly referred to in which it has been, as it were, injected into the schists apparently under enormous pressure).

Over the greater part of the map of Hazara the whole of the gneissose-granite and schistose country is represented with one colour. It would have been possible no doubt to have traced out

each individual band of the granite in its course through the enclosing rock, but having sampled a few parts of the country, such as the Black' Mountain and the neighbourhood of Mansehruh, and having besides in previous years devoted much time to the same toil (see map of Dudatoli, Rec. G. S. of I., Vol. XX, pt. 3, 1887), I came to the conclusion, considering the uniformity of the country, that minutely mapping such details would not have sufficiently repaid the enormous amount of time that it would have required.

In the Black Mountain, where, during the campaign against the Akazais and Hassanzais, some months were spent in the quiet punishment of occupying the country and consuming the crops, I had a good deal of spare time, and this was turned to the best use I could put it by making as minute a survey as I was able to on the small-scale map available.

In the descriptive portion of this memoir such details as were gathered at that time will be found systematically arranged.

The gneissose-granite of Hazara is a rock of extremely characteristic aspect, and when once seen is not likely to be easily forgotten. It exactly reproduces the mineralogical composition, the structural characteristics, and the peculiarities of habit that I have been long familiar with in the gneissose-granite of certain places in the Lower Himalaya of Garhwal and Kumaun such as the Chor Mountain, Kalandanda (where the sanatarium of Lansdowne now is), and Dudatoli Mountain. There is also no reason to doubt that it is the same rock as occurs in Kashmir along the Pir Panjal axis and elsewhere, called Palæozoie and Archæan by Lydekker (Mem. G. S. of I., Vol. XXII), and that it is the same as Stoliczka's central gneiss, at least largely, and as the Dalhousie and Chamba gneissose-granite described by McMahon.

Mineral composition of the gneissose-granite.

Mineralogically the rock is a granular aggregate of quartz, felspar, and white and black mica with the accessory minerals, schorl, garnet, magnetite, apatite, plagioclase. In some places, and especially near the edges of the bands and rock masses, it is porphyritic by the presence in it of large crystals of orthoclase in binary carlsbad twins. These are

sometimes of great size, and vary from 2 to 8 inches in length, but generally they average 3 or 4 inches only. The larger ones have often only a very vague outline in the rock as if their boundaries had become indistinct from the reaction of the still molten magma upon them whilst the rock was in a half-consolidated state. They also pretty generally shew magnetite and apatite, included within them.

In some of the finer-grained and smaller veins of the rock (aplite apophyses from the main mass) among the schistose rocks the presence of schorl in minute and broken crystals is especially noteworthy, the latter as near Mansehruh giving the rock an appearance of being banded.[1]

Along with the porphyritic character there also occurs another feature which is extremely prominent near Mansehruh. I refer to the frequency and number of included fragments of schist and quartzite which throng the rock. Many of these included fragments are as large as the crystals of felspar, 3 or 4 inches long, but others are still larger and rounded in appearance. So full of included fragments is the rock that they may be found without difficulty every ten yards of exposed rock in the stream-bed. Some are as large as a foot across, and occasionally they are so crowded together as to give almost the appearance of an agglomerate.

Although inclusions of schist, etc., have been noticed and remarked by me in other localities, at the Chor Mountain, etc., I have never found any place where they are so pronounced as in this area round about Mansehruh.

Wherever the rock has been intruded into the schists in the form of a rather fine irregular fringe at the margin of the main mass (apophyses) it is of a finer grain, slightly more felspathic as a rule, and contains a greater amount of schorl, no black mica, and but little white mica.

[1] About 60 yards up the Bela stream from the Mansehruh plain an aplite apopyhsis of the gneissose-granite cuts through the schists. It varies much in mineral composition at different points. In some places there is a large amount of schorl, in others a larger amount of white mica. In others, again, the quartz and mica seem to make up the rock to a large extent. Porphyritic felspars, though developed in some places towards the centre of the thicker or more swollen parts of the veins, do not as a rule shew up to quite the same extent as in the gneissose-granite massif.

I shall call these veins aplite veins (cf. Teall, "British Petrography," p. 291). Although most of these veins can only be looked upon as being of an eruptive origin in the main, it is possible that segregation has had a certain share in the operation and brought about their diverse mineral composition. Of such an origin doubtless are the pegmatite veins of Panjigali in the Black Mountain, which occur among the ordinary gneissose-granite, and exhibit large schorl crystals and felspar crystals, together with a banded structure of finer quartz and felspar.

Structure of the gneissose-granite.

The above mineralogical characteristics are, of course, common to a great many granites in a great many countries, but when those characteristics are considered in connection with peculiarities of structure, and when both are considered in connection with peculiarities of habit in the rock as a whole, it is then that the close resemblance between the gneissose-granite here, and in those parts mentioned by me in the Lower Himalaya, becomes approximately demonstrated.

The types of structure in the gneissose-granite may be divided into the groups given below, which is a reproduction of the classification given originally by me.[1]

(A) FOLIATED { (1) *Tabular-foliated*—absent or very rare in Hazara.
(2) *Lenticular-tabular foliated*—very common. }

(B) SEMI-FOLIATED { (1) *Augen*
(2) *Porphyritic augen* } Common.

(C) NON-FOLIATED—*Granitic*—Common.

Of these three groups, A, B, C, the last appears to be the original condition in which the rock first solidified after intrusion among the sedimentary rocks of the region; whilst the modified forms, A and B, have been, as a rule, derived from C by the mechanical action of pressure metamorphism. General McMahon, I should mention, regards similar foliated and semi-foliated gneissose granites of the Himalaya as owing their structure to differential movements of the

[1] Rec. G. S. of I., Vol. XX, p. 139.

liquid mass of the acid magma whilst still in a semi-molten or viscid condition. While acknowledging the great weight due to the opinion of such an authority on Himalayan petrology, I am reluctantly compelled nevertheless to dissent from his view and to conclude that the greater part, if not all the foliation and linear arrangement of the ingredients of the gneissose-granite, has been due to a superinduced action, to a form of dynamic metamorphism acting on the rock since the time it became a solid stationary mass. My reasons will be evident by themselves from what I shall say in the sequel.

Microscopical descriptions of typical examples of A, B, & C.

The following is a brief outline of the features shewn by the types A, B, & C referred to above. Good examples of all of them may be well studied between Makranai and Ril, Black Mountain :—

C. *Granitic type.* In this the rock shews no subsequent lamination of the minerals and no eye structure. The coarsely granular crystalline ground-mass is thickly dotted with porphyritic felspars of normal shape, the outlines alone being a little blurred. They are oriented in every direction indiscriminately. A good example of this type is to be seen one mile N. E. of Mansehruh along a little ridge of tors standing up out of the plain; also at Diliari and near Sambalbut in the Black Mountain.

B. (1) *Augen*; (2) *Porphyritic augen.* The terms here explain themselves. The granular crystals present in the rock when non-porphyritic and the porphyritic crystals in the latter are no longer of an irregular or a regular crystalline form. On the contrary, the former are drawn out at their extremities into eye or lens shaped bodies, but still separated one from the other, whilst the latter (the porphyritic crystals) have their corners rubbed away, the material being redeposited at right angles to the pressure, thus producing a very similar large eye or lens shaped body. Examples occur on the road from Makranai to Ril.

A. (1) *Tabular-foliated*; (2) *Lenticular-tabular foliated.* A. (2) is a very common form. In it the previously formed eyes of quartz and felspar have been so dragged out, or rolled out

by pressure with differential movement, that the ends of the one overlap the ends of the next to it. A bridge between two grains is thus formed, and we have lenticles connected by a narrow band of broken-up and re-cemented quartz and felspar powder. This particular and common type of structure is figured by me, Rec. G. S. of I., Vol. XX, Pl. I, fig. 3, and Vol. XXI, Pl. II, fig. 10, Pl. III, figs. 11 and 12. Three or four miles north of Mansehruh, where the rock is less markedly porphyritic, we have abundant examples of this structure. In the Shal N., Black Mountain, it is, however, seen to the greatest perfection (see on p. 72 for microscopical section of this rock). A. (1) is seen near Kand, Black Mountain. It represents the extreme of dynamical action on the gneissose-granite. The lenticles no longer remain either isolated as in the augen, nor united by a bridge as in the lenticular-tabular, but are now drawn out perfectly flat and tabular.

All the above foliation effects included under the headings A and B are more marked in the thinner bands of the gneissose granite (except in the case of the irregular ramifying apophyses) and at the margins of the thicker ones, than elsewhere.

Habit of the rock in the field.

From observations made by me near Mansehruh, Gurhee-Hubeeb-ooluh, in the neighbourhood of Lalo Gulee, in the Black Mountain, and from a few cursory notes made in Agror whilst travelling rapidly, I find that the relation between the gneissose-granite and the enclosing schists is of precisely the same kind as I have found to be the case in the Lower Himalaya.

In making an isolated traverse across any portion of the country in which these rocks occur it would be very easy to go away with the impression that the two were mutually interbedded and of the nature of schists and gneisses. The foliation of the two rocks would seem to be perfectly parallel, and one might never come across any of those interesting exceptions which shew their unity to be only apparent and not real. Hence the conclusion come to by Mr. Wynne and referred to above (p. 49) is a very natural one at a certain stage of enquiry. It is only when the individual bands of the

gneissose-granite are studied and traced out laterally as well as forward and backward that we find them to be by no means continuous. They are then seen to die out and reappear again, to thin away and thicken, and sometimes, but very rarely, to cut at a very acute angle across the foliation planes of the schist. Near Mansehruh, as recorded by Mr. Wynne and as seen by myself, we have very conclusive evidence for the intrusive nature of the rock from its mode of occurrence in the field.

In the sketch section below I give an example of the invasion of the quartzite by very distinct veins of gneissose-granite. The intruded rock, moreover, though without doubt belonging to the same magma as the great mass of the gneissose-granite, differs slightly by being of finer grain and with a larger amount of felspar and less of the ferro-magnesian minerals, especially of the dark mica. This difference, however, is exactly what would be expected to occur in a narrow vein which has been forced in across the bedding of the schists.

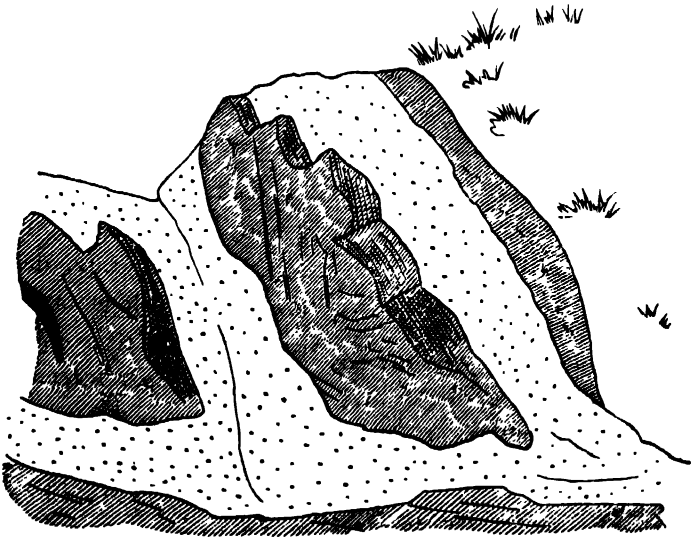


Fig. [illegible].

About ¾ miles N.E. from the D. B. Mansehruh along the Gurhee-Hubeebooluh road.

Note.—The shaded portions are quartzite and the dotted granite.

With reference to the preceding figure it may also be remarked that though there is a slight banding of the material of the vein there is no foliation at all.

In the next figure (fig. 2) I give another example of a similar kind of intrusion. Here also there is a rough banding of the material of the vein, inasmuch as the schorl in minute specks lies parallel to the walls of the vein. The vein has, however, no true schistosity with tendency to split along it.

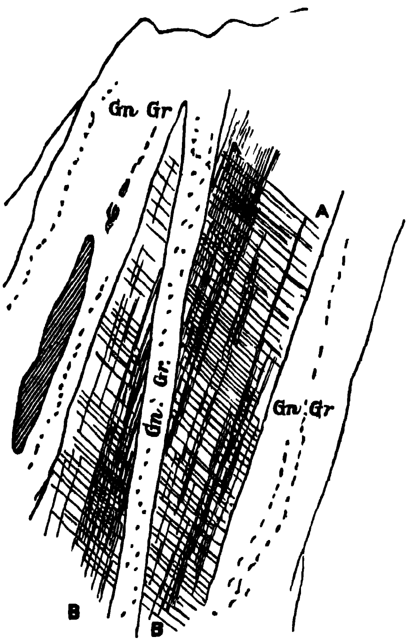


Fig. 2.

NOTE.—Gn. Gr. = Gneissose-granite veins.
A B = Schist and quartzite.

Of the three bands seen in figure 2, the middle one cuts quite diagonally across the foliation and original bedding of the schistose arenaceous rock. In the diagram, A B is the direction of original bedding of the schist, and A A the direction of splitting in the rock, along which there are fine films of mica developed.

Other effects of a similar kind will be detailed in the descriptive part of this book.

One habit of the gneissose-granite has already been alluded to in the paragraph describing the more highly metamorphosed rocks. I refer to its appearance of having been forced into the schist, as it were, under enormous pressure, so that it has not merely invaded them in a lethargic way in broad distinct bands, or with but an outer fringe of apophyses wandering and ramifying through the rocks, as I have just described, but has also *permeated* the rock along the foliation planes in a great system of minute veins all parallel (though sometimes with wavy parallelism) to one another. In some

cases it would seem as if individual crystals of the felspar of the gneissose-granite had migrated from the intruding rock into the intruded schist. Some examples of the more intense form of this permeation or injection of the schists by the gneissose-granite will be given later, along with the microscopical details. The Shal N., Black Mountain, exhibits numerous examples of this structure.

Microscopical examination of slices of gneissose-granite.

I now proceed to a microscopical description of a few typical slices of the gneissose-granite in its various modifications. No. $\frac{9}{487}$, half a mile north of Mansehruh. In the hand-specimen it shews a granite texture with only slight parallelism of the component minerals, and is slightly porphyritic, the felspars having all the appearance of being orthoclase, as occasional binary twinned porphyritic crystals, 1 to 2 inches long, seem to indicate. Nevertheless, under the microscope, much of the felspar thus named comes out with a very distinct microcline-like structure, others shew a parallel striped structure resembling ordinary albite twins of plagioclase. Some of this characterising the smaller felspars appears certainly to indicate plagioclase. Most probably the microcline and striped appearances are pressure-induced structures. The triclinic felspar is mostly idiomorphic with sharp outlines, whilst the porphyritic orthoclase or microcline crystals shew a considerably worn outline, as if the molten magma surrounding them had slightly re-fused them. Considerable saussurisation of the felspars has taken place in patches within the larger crystals Within the larger porphyritic crystals of felspar there is also an appearance as of included smaller crystals of felspar which are completely altered into a grey dusty decomposition product, also a few quartz granules and brown mica plates. In the rock-mass in the field these features can often be seen in the larger 5-6 inch crystals of felspar. Quartz is visible in the slice in considerable quantity, filling in the spaces between the other minerals. The margins of the quartz-grains, and the differently polarising polysynthetic mosaic or tesselated structure into which it breaks up between crossed nicols, shew much powdering up of the edges of the grains, although the rock is not typically

crushed in any way and shews no definite foliation. Brown mica occurs in tabular plates with jagged edges partly decomposed with development of magnetite along the cleavage.

Accessories present are magnetite (chiefly confined to the mica), white mica, and minute garnets.

No. $\frac{9}{498}$, a little south of Panodee near Mansehruh. This is a semi-foliated variety of the gneissose-granite, non-porphyritic. In the hand it is seen to be composed of quartz, white felspar, white mica and schorl. Its foliation is much more distinct than that of the last specimen, though still far below the more marked examples of pressure foliation.

Under the microscope the larger felspars shew binary twins and are much altered. They are doubtless orthoclase. No microcline-like structure is noticeable in these crystals; but some few smaller crystals exhibit vaguely through the dusty decomposition products the repeated albite twining of plagioclase. Quartz is well represented in large grains of irregular shape, giving undulose extinction over their central parts, and with a border of crushed material polarising in a confused mosaic. In many places the state of strain in the middle of a grain, indicated by the undulose extinction, passes by a gradual transition into a cracked state at the margin, with aggregate polarisation.

The schorl is irregularly and locally developed in the rock in somewhat irregular grains. The white mica is in jagged packets sometimes, the fisibility of the rock being due chiefly to the arrangements of these in layers.

Magnetite as an accessory appears to be only developed by the composition of the schorl.

In this, as in all the rocks of this class, schorl is only present when black mica is absent.

No. $\frac{8}{881}$, 1 mile south of "D" of Doguh. This also is a semi-foliated variety like the rock just described. Contains felspar,

quartz, and a pale greenish mica. The felspars appear dull white in the hand-specimen, and dusty grey in the section. Pseudo-microcline structure is noticeable in some of them. They are much broken at the edges, forming a quartz-felspar mosaic. Alteration product of one of them in tassels with development of secondary mica. The quartz is much the same as in the last specimen, but there is also secondary quartz running in bands through the felspar. The mica is torn into shreds, broken up, and bent. Accessories are apatite included in the felspar, and a very little magnetite.

No. $\frac{8}{873}$, north-east of 2198 ft. hill, Sirun river, near Turbela. In the hand this specimen appears to be almost of the tabular-foliated type. Under the microscope it is seen to be a completely rolled out and powdered up rock composed chiefly of layers of quartz and felspar. The latter, when the irregular grains can be distinguished in the much-disfigured mosaic, is seen to contain a large number of inclusions of the same sort as was noticed in the felspar of No. $\frac{8}{884}$ (see page 58). Between the layers of quartz felspar mosaic, dark mica chiefly, but also pale mica, lie in parallel wavy lines, running round the occasional eyes of felspar and producing with the magnetite, which also follows this course, a genuine foliation of the rock.

No. $\frac{9}{499}$, sixty yards south of main gneissose-granite boundary, 1 mile west of Bela N. on the road to Mansehruh. Aplite vein, very coarsely banded, 2 feet thick, among quartz-schists. Composed chiefly of felspar and quartz, the former ophitic in large crystals round the latter, which meanders in veins and strings through it. There is a peculiar striping of the felspars, giving between crossed nicols in certain aspects the appearance of a microperthitic intergrowth. It is probably a pressure effect. Mica, dark and pale, is present in very small quantity.

No. $\frac{9}{500}$, Bela N. Fine-grained aplite vein in coarser gneissose-granite. Has a fine-grained almost euritic texture, and is composed of an intimately mixed quartz-felspar mosaic. White mica is present, and also schorl. The coarser rock in which the vein occurs

shews large felspars with apparently microperthitic intergrowths. The quartz, as usual in most of these rocks, shews evidence of crushing with production of polysynthetic aggregates.

No. $\frac{8}{881}$, Shal N. between Kand and Seri, Black Mountain. A porphyritic-augen and lenticular-tabular variety. In the hand-specimen this rock is a beautiful example of the so-called 'flaser' type of deformation of a rock by enormous pressure, which has been sufficient to cause the various constituents of the rock to, as it were, flow like a semi-liquid body. I can conceive of no other cause than intense pressure, exerted in three directions, and greater in one than in the other two, to have produced such a rock.

I give below (fig. 3) a rough outline sketch of the rock fragment which, poor as the drawing is, speaks for itself. In the lower portion of the right-hand side of the block there are two large eyes of felspar considerably deformed by pressure, and with the rest of the fine material of the rock flowing round them, as it were. At the top of the specimen there is a great tabular layer of felspar which represents probably several porphyritic crystals of felspar which have been welded together by the rolling-out process, just as in the familiar illustration of a layer of pastry. The finer material of the rock also shews numerous beautiful examples of eye structure on a small scale.

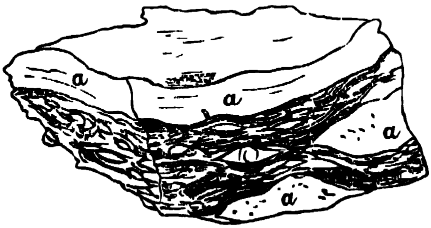


Fig. 3, No. $\frac{8}{881}$. *a a.*—felspar eyes and layers.

Seen under the microscope the felspars are water-clear and cannot be distinguished from the quartz, except by the needle-like inclusions which they contain, by their occasional binary twins, and by the microcline-like plaid appearance of the grains. Of original crystal outline there is none left. The felspathic material, which swells out here and there into lenticles with nodes between, shews by its undulating boundaries how intense was the deformation it sustained. Between crossed nicols

the portions of these layers which still retain their original molecular structure shew up clearly by extinguishing light more or less simultaneously over their whole area; on the other hand the intervening bridges of material, that have been crushed and reunited, shew a complicated mosaic with aggregate polarisation. The quartz layers give evidence of the same rolling-out process. Both brown and white micas are represented, the latter predominating slightly. They follow along the foliation, wrapping round the eyes of felspar in a way that must be seen to be believed. A more perfect example of this structure than the present specimen affords could not be imagined. Garnets may here and there be detected by their isotropic behaviour, etc., but they have been cracked and broken and rolled out into lenses just as have the quartz and felspar.

Plate I, figs. 1 and 2, are photographic reproductions of drawings of a slice of this rock in natural light and between crossed nicols respectively. The large crystal at the top represents a singly twinned felspar, cut through by cracks which have displaced the line of the composition face. The rolled-out layers of quartz are well seen on the right, and an elongated and crushed garnet is seen in the centre with its lower extremity drawn out into a number of lozenge-shaped fragments.

The above rock, if compared with the description and drawing of the Beinn Vuroch gneissose-granite (see Teall's Brit. Petrography, p. 325 and Pl. XLIII), will be seen to be almost identical with it.

No. $\frac{8}{882}$, from the same locality as the last. In the hand-specimen the beautiful glassy felspars, almost meriting the name of sanidine, exhibit carlsbad twins in perfection, notwithstanding the deformation by pressure which they have suffered. Generally the rock resembles the last described, but the mica is more prominently visible, and there are more garnets. There are a few grains of plagioclase present, but no microcline structure.

No. $\frac{8}{890}$, right bank of Indus river west of Ghazikot. A lenticular-tabular foliated variety. It is a more thinly foliated rock and shews a slightly more complete pressure deformation of the flaser type

than the last. The rock is more quartzose than an ordinary gneiss or granite, the quartz being present in the usual polysynthetic aggregates, but so abundant, together with a large amount of brown mica, that one is tempted to regard the rock as a mica-schist among which a few felspars have migrated from the neighbouring gneissose-granite. The latter shew carlsbad twins, but their outlines are very ragged and broken.

No. $\frac{8}{886}$, junction of Shal N. with Indus. A vein in foliated dark mica-schist. Under the microscope it shews patches of various degrees of fineness, indicating either a euritic or microgranulitic ground-mass, or as seems more probable a final stage in the pressure metamorphism of a normal granite in whieh the felspars, full of inclusions, have become almost entirely destroyed, there being nothing left of them but extremely ragged fragments. Quartz is present in the usual polysynthetic grains. Garnets are very prominent in idiomorphic grains at the edge of the vein in the micaceous part of the enclosing schist.

No. $\frac{9}{503}$, $\frac{1}{2}$ mile north of Mansehruh. A foliated variety from near a trap dyke. It exhibits beautiful microcline-like and finely twinned effects in the felspars, and sometimes also apparently microperthitic intergrowths : carlsbad twins prominent, and *in situ* breaking-up and powdering of the margins of the quartz and felspar, with production of mylonitic structure. Brown mica, white mica, and tourmaline are present.

No. $\frac{8}{879}$, Shal N., Black Mountain. A hypersthene granitite (foliated). This rock, which I have not found elsewhere in the area described by me, contains quartz, felspar (chiefly triclinic), mica, and hypersthene. The presence of hypersthene in so acid a rock with free quartz recalls the charnockite recently described by Mr. Holland from the Nilgiri and Shevaroy Hills, Madras. The hypersthene is apparently being converted into brown mica. The rock has been well foliated by pressure. It is possible it may be genetically related to the ultra-basic rock No. $\frac{8}{823}$ to be presently described.

(5) *Trap dykes intrusive among (1), (2), (3), and (4).*

Generalities.

A few basic trap dykes are known in Hazara. They are always holocrystalline, and may be generally described as plagioclase-augite rocks or dolerites. Nowhere that I am acquainted with is there any outflow of the basic rock in the form of a subaerial lava stream, such as those which occur abundantly in the Lower Himalaya, *e.g.*, north of the Dudatoli massif. (Rec. G. S. of I., Vol. XXI, pt. 1, 1888). On the contrary, the rock is everywhere a dyke rock; and, if lava streams were ever formed in connection with them, all traces of them have since been swept away by denudation.

Structure and variations.

The variations which occur in the mineral composition of the rock at different localities seem to be purely due to the effect of metamorphism of the original plagioclase-augite rock. The rock varies in texture from a fairly coarse dolerite to a fine aphanitic rock, the colour from mottled greenish-black and white to dark greenish-black. Foliated varieties with change of the rock into a hornblende-schist occur at the edges of dykes cutting through the gneissose-granite of the Indus river. Examples will be given presently. A columnar variety of trap with five-sided columns occurs due west of Shingli on the ridge.

Habit of the rock.

The basic traps of Hazara do not occupy any large surface of the country; but they are generally found in the form of narrow bands or dykes roughly parallel to the foliation of the intruded rock, which latter, from the fact that in certain places the dykes cut across both the schistose series and the gneissose-granite intrusions, and also send off small veins into them, must be judged to be older than the traps. A few examples may here be given. At the junction of the Shal N. with the Indus river, Black Mountain, the trap would appear certainly to be younger than the rock among which it is found, because it cuts through the foliated schists and also through the gneissose-granite

veins in the schists. A diagram of the above relationship I here append (fig.4). Further examples may be found in the schistose-slate

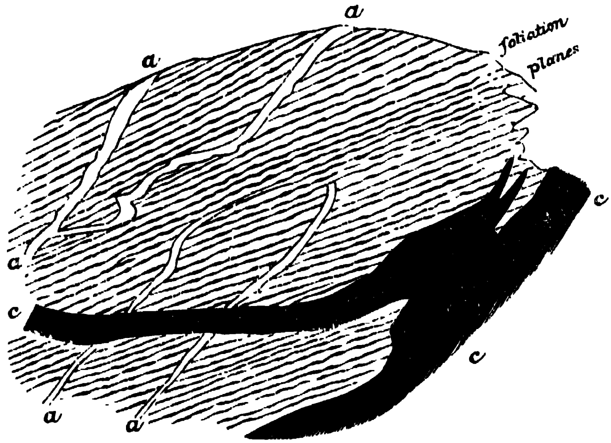


Fig. 4.

aa — Veins of gneissose-granite intruded in dark schist.
cc — Trap dyke cutting across both.

hills of the Gundgurh range and in the Tanol quartzites and Infra-Trias limestone near Chooeean on the same hill range. I have never found any trap dykes intrusive in any of the rock formations higher than the Infra-Trias.

I shall now proceed to describe a few of the most marked varieties and passage forms of these rocks.

No. $\frac{9}{506}$, $\frac{3}{4}$ mile north-east of Mansehruh, intrusive among the gneissose-granite. A typical plagioclase-augite rock. The former mineral appears in good lath-shaped sections of microtine habit, clearly twinned after the albite and pericline plans, and sometimes possessing zonal inclusions. The augite occurs in very pale straw-coloured irregular grains, moulded round the lath-shaped plagioclases, and, as regards the individual grains, being ophitic round the smaller felspar crystals. If possesses occasional twins. It very occasionally shews changes into a pale greenish decomposition product which is sometimes pleochroic. Titaniferous iron ore is prominent in irregular

plates or aggregates of triangular sections, and is generally surrounded by a margin of the greenish decomposition product. A section of this rock as seen in natural light is given in Pl. I, fig. 3.

This rock, together with the next three transitional varieties which will be described, appear to be identical in their mineral composition and structure with those described by Teall (British Petrography, pp. 154, 197, Plates XIX—XXI) from the Scourie dyke, Sutherland. They also shew a perfectly graduated series from a rock of the type just described to a normal, fine-grained hornblende-schist. The plates which I have given are photographic reproductions from drawings made with the aid of the *camera lucida.* Each represents, therefore, as faithfully as I could do it, an actual portion of the slide as seen through the microscope.

Nos. $\frac{9}{609}$, $\frac{9}{610}$, $\frac{9}{611}$, all from near Mansehruh. They shew modifications of the previous example. They are generally somewhat finer in grain, and exhibit various stages in the change of the augite into amorphous green matter. In the second of the drawings given, shewing these metamorphic changes (Pl. I, fig. 4), rock No. $\frac{9}{611}$, about half the augite has been so converted, whilst in $\frac{9}{610}$ there is hardly any trace of augite left in the slice. The plagioclase also in the last has become coloured a pale buff colour, and in addition shews a few traces of crushing.

The next examples to be described are from another locality, but from a dyke of the same kind. They are selected as being very good examples of the final stage of conversion of the plagioclase-augite rock into a hornblende-schist.

No. $\frac{8}{891}$, right bank of Indus river opposite Ghazikot, Black Mountain, can scarcely be distinguished under the microscope from $\frac{9}{610}$. In the field it penetrates the gneissose-granite, cutting diagonally across its edges. At its sides it passes into a fissile foliated variety described next.

No $\frac{8}{892}$, side of dyke from above locality. It is a foliated variety of the last. The foliation is very noticeable under the microscope, and is of excatly the same character as that of the gneissose-granite,

that is to say the felspars have been dragged out, forced over one another, and broken up and re-arranged into lenticles and bands. Nevertheless they are still quite recognisable in parts, and shew characteristic twinning. Of augite, the few grains remaining are scarcely definite enough for recognition. The intervening layers of amorphous green material are its representative; and they wrap round it and run in sinuous lines among the other constituents of the rock. The fine-grained mosaic of a clear colourless mineral, side by side with the evidently crushed and broken plagioclase, is noticeable as being a further stage in the development of a hornblende-schist. The black titaniferous iron ore has become rolled out into long thin layers and lenticles parallel to the direction of foliation. It is marginally altered into or surrounded by a bright yellow or orange substance inert between crossed nicols. Pl. II, fig. 5, represents a slice of this rock which may be called a foliated epidiorite.

No. $\frac{8}{893}$, from the same locality—see Pl. II, fig. 6. This rock fragment gives us the last link in the chain of examples, for it is a normal hornhlende-schist. The pleochroic hornblende, varying from deep bluish-green to pale greenish-yellow with characteristic cleavages and extinctions, could not be more manifest. The slightly elongated grains have their long axes parallel to the foliation, and between layers of them comes granular quartz. There is no sign of plagioclase left in the rock, although there were many broken up distinct fragments of it in the last-described-rock. It is possible there may be a certain amount of secondary felspar present among the clear granular material, but the only grains sufficiently defined for testing with convergent polarised light gave uniaxial figures.[1] The fine granular material with high refractive index is most probably sphene, and may be accounted for by alteration of the titaniferous iron ore, of which scarcely anything is left in this rock.

Thus, uniting the observations made on the specimens from No. $\frac{9}{506}$ to $\frac{8}{893}$, we have a fairly connected history of the development

[1] The large white patch in the figure of this rock with tremolite (?) crystals in it seems to be a secondary felspar mosaic with convergent polarised light. It is an exception to the general structure of the rock.

of a hornblende-schist from a plagioclase-augite rock, agreeing stage by stage with those figured and described by Teall from the Scourie dyke. A rock, which was manifestly from its structure and composition a massive igneous rock composed of plagioclase, augite, and titaniferous iron ore, has been converted, doubtless by dynamic metamorphism, into a fissile schistose rock composed of hornblende, quartz (possibly also granular secondary felspar), and sphene.

No. $\frac{8}{871}$, thin dyke Kirpiliyan, Indus river, and No. $\frac{8}{875}$, dyke Lalo Gulee, Indus river. These are both further examples of foliated epidiorites, and indicate an origin similar to that of $\frac{8}{892}$. The former is composed of layers of granular hornblende and quartz with some brown mica and nests of sphene; the latter is even more pronouncedly a hornblende-schist than even $\frac{8}{892}$, and the long prismatic hornblende crystals are frequently broken into jointed lengths.

No. $\frac{8}{876}$, 2 miles N. W. of Daree where the Sirun river joins the Dore river. This is a similar schistose epidiorite, but more indistinct and less re-crystallised after crushing.

A few more examples of these dyke rocks may be given :—No. $\frac{8}{884}$, occurring in the gneissose-granite $\frac{1}{2}$ mile south by east of the "D" of Doguh is a holocrystalline rock more nearly resembling the plagioclase-augite rock, or dolerite, No. $\frac{9}{508}$, than anything else; but it contains, besides the minerals in the latter, a deep clove-brown mineral, intimately connected with the titaniferous iron ore and shading off into it. It is slightly pleochroic (brown to violet-brown colours), with strong double refraction, and may be a form of pyroxene. The rock possesses a peculiar striping and fissuring in one direction, and along the lines or fissures there is sometimes a green amorphous mineral.

No. $\frac{8}{894}$ is simply a coarsely crystalline variety of $\frac{9}{510}$, with porphyritic idiomorphic plagioclases shewing zones of growth, and with inclusions of jointed rods of apatite and granules of augite. There is a little brown mica also in the slice. In the diagram below (fig. 5) a crystal of plagioclase is shewn with the outer zone not quite symmetrically disposed around the central one. In the latter darker part the granules of augite are confined.

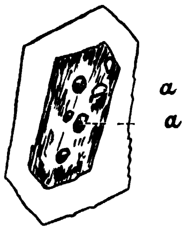


Fig. 5.

a. a. — Granules of augite included in the darker central part of the plagioclase crystal.

No. $\frac{8}{867}$, dyke a little north of Seree Sher Shah. This rock resembles $\frac{9}{510}$ entirely, and like it exemplifies wonderfully well the *in situ* breaking-up and change of the augite into an amorphous green mineral.

No. $\frac{8}{868}$ resembles the last, but is finer-grained.

Two examples may now be given of other basic dykes, which differ somewhat from those hitherto described by the fact that the augite as well as the plagioclase is present in irregular crystalline (hypidiomorphic) forms with twinning very common. The last three examples stand apart by themselves.

No. $\frac{8}{865}$, dyke ¾ mile west of 6,168 ft peak, north-west of Nummul, Jhelum valley. A plagioclase-augite titaniferous iron-ore rock. The plagioclase is saussuritic, giving between crossed nicols only vague uniform polarisation effects. There are traces in the rock of micropegmatite. The augite, unlike that of the dykes already described, seems to have crystallised out comparatively early during the solidifying of the rock. It is largely represented in the slide in long crystals, is of a pale straw colour, very fresh-looking, and generally twinned in the ordinary way, the twinning plane being 100. Between the two broad twin lamellæ there are generally a few very fine twin lamellæ interposed.

No. $\frac{8}{866}$, dyke south of Sobruh, intrusive among the schists. A similar rock to the last. Some of the plagioclase crystals are quite clear, and others are saussuritic, others again are clear marginally and opaque within. There is also a little quartz and mica in the rock, besides titaniferous iron ore as usual.

No. $\frac{9}{512}$, dyke among graphitic schistose slates, near Bandee Gundgurh range. In the hand a pale grey compact rock. The microscope shews it to be a much altered very fine-grained rock, the original constituents of which cannot be made out. Calcite in veins and epidote in granules are secondary products discernible in the slide.

No. $\frac{9}{508}$, 4 miles north-west of Gudwaliyan, Gundgurh range, in dykes banded with limestone belonging to the Slate series. A rock similar to the above and evidently part of the same intrusive band. The original structure of the rock has been completely obliterated with development of epidote in large irregular grains, and of calcite.

No. $\frac{9}{505}$, Sunvai near Lalo Gulee, associated with the gneissose-granite. A crushed foliated rock of greenish colour. Contains hornblende and plagioclase among the original constituents; but the rock has been partly serpentinised with production of picrolite, giving deep violet polarisation colours. Calcite and epidote are also well represented. The rock might doubtless have become an ophicalcite if more crushing and dynamo-metamorphism had supervened.

Appendix: Rocks found as river boulders in the Indus river-bed.

Remarks.

The country to the north and north-west of Hazara and the Black Mountain, along the course of the Indus river, is inhabited by a number of independent hill-tribes, and up to the present is impossible of access to anything but an armed force. I, therefore, made a collection of the river boulders near Lalo Gulee, with the object of illustrating, as far as possible, the nature of the parent rocks in that inaccessible region. I give below a list of these, with a few remarks about the most important of them.

No. $\frac{8}{581}$ is an example of the most common rock found in the river-bed, *viz.*, the gneissose-granite which I have already described as being the rock most in evidence at the surface forming the high hills round about. It is present in the river-bed in immense blocks of several thousand cubit feet content, and slightly rounded, which lie along certain reaches of the river. Microscopically it exactly corresponds to the most typical examples of gneissose-granite described above. The orthoclase is specially beautiful as regards the inclusions or schillerization products (probably sericite) which appear in it crossing one another in regular lines parallel to the cleavage.

The next set of rocks, which can be made out from the boulders, are a series of rocks, mottled white, and dark-green, sometimes foliated

and sometimes massive. Nos. $\frac{8}{832}$ to $\frac{8}{840}$, inclusive, illustrate this series and are apparently all connected genetically with one another. They all possess a highly crystalline-granular structure, and are composed in different ways of plagioclase, augite, hornblende, garnet, rutile, iron-oxide, and secondary epidote and quartz. Most of them contain felspar, and this is altered almost completely to a dead-white saussuritic material, dull and opaque in transmitted light, and giving scarcely any colour phenomena between crossed nicols. In $\frac{8}{832}$ especially, and also in many others, *e.g.*, $\frac{8}{833}$ to $\frac{8}{835}$ clear colourless epidote is intergrown with vermicular quartz and appears to have arisen from the decomposition of the felspars, among which it lies in irregular ragged ophitic masses. Deep amber-coloured rutile granules are fairly characteristic. The augite is green, and is found associated in close granular connection with the garnets, which are very common. This connection is very noticeable in $\frac{8}{834}$, where the mineral, by analogy presumably augite, possesses none of the ordinary characteristic cleavages of that mineral, but only irregular cracks, as if it were mimicking the associated garnets. In $\frac{8}{835}$ again, where the same association of the two minerals is seen, there are good examples of augite shewing characteristic cleavages. $\frac{8}{835}$ also contains bundles of picrolite. Hornblende in this series of rocks ($\frac{8}{832}$ to $\frac{8}{840}$) is very common, being present in nearly all the slides. It occurs in beautifully preserved short prisms, perfectly fresh-looking, with cleavages fine and distinct. Its colours are generally deep and bright, and the pleochroism very pronounced. In $\frac{8}{836}$ the hornblende is present in smaller grains, and there is a good deal of quartz also present. In $\frac{8}{835}$ the hornblende appears to have arisen from the augite by uralitization, as it keeps the same ophitic shapes as the augite. In $\frac{8}{837}$ the hornblende has a marked tendency to be drawn out and to lie parallel to the lenticular-tabular quartz-felspar layers. In another boulder, $\frac{8}{839}$ (see plate II, fig. 7), the hornblende with garnet, rutile, and iron ore make up the whole of the rock; and this seems to have its complement in $\frac{8}{838}$, which is made up entirely of crushed felspar and quartz, the former as usual

saussuritic. Probably the two boulders are different portions of a very coarsely banded hornblende-gneiss.[1] Garnet is common in these rocks, associated with augite as referred to above. It is in irregular grains, sometimes shewing crystal outlines. It also occurs without augite in some of the rocks. It is pink in colour and traversed by irregular cracks, limpid and clear and without inclusions. Quartz is not common. There are only a very few examples of it in small grains, lying along with the felspar and possibly having arisen secondarily by crushing and metamorphism of the felspar. Iron ore is sparsely represented. In addition to the above minerals, hypersthene and olivine (?) are doubtfully present in one rock $\frac{8}{840}$.

The above gives an idea of the general mineral components of this series of rocks. As regards their structure, they are sometimes massive crystalline rocks in which no foliation can be detected, and on the other hand they are often foliated very distinctly. That these rocks form a connected series, the individuals of which pass into each other, seems to me indisputable; and it does not seem improbable, if one may make a guess founded on such scanty data, that they represent a thoroughly holocrystalline plutonic massif or plexus, originally consisting essentially of plagioclase and augite, with which the basic dykes, already described, are in deep-seated connection. The modification of them into foliated rocks with augen and lenticular-tabular structures, and the development of hornblende from augite, also seem to be plutonic effects of dynamic metamorphism, corresponding to the effects we have already traced at the margins of the dyke rocks.

No. $\frac{8}{841}$ stands alone among these boulders as a fine-grained dolerite, composed of lath-shaped plagioclases, pale brown augite in very small rounded grains, and magnetite.

[1] Since writing the above I have made the acquaintance near Salem, Madras Presidency, of a set of hornblende-garnet rocks which compose whole ridges. They also and an ultrabasic olivine bearing rock resembling that to be presently described appear intimately connected with serpentinised dunites.

No. $\frac{8}{842}$ likewise stands alone as one representative of the ultra-basic division of rocks. It is a crystalline-granular association of olivine, partly altered along fissures into serpentine and iron oxide, pale green augite, sometimes slightly crushed and schillerised in places, and hypersthene (?) visible doubtfully in two places in the rock slide. There is no trace of any felspar or quartz. (See plate II, fig. 8.)

Nos. $\frac{8}{843}$ to $\frac{8}{845}$ are somewhat doubtful rocks. $\frac{8}{845}$ is a serpentinised rock of some sort with colourless hornblende (tremolite) visible in it, much cut up, and invaded by the serpentine. The other two rocks are complete puzzles to me. They possess large plates of some mineral, broken up into small disconnected patches extinguishing light together, and between the separated ragged grains of which there is a clear colourless mineral running as veins through the rock. Mr. Holland suggests the former to be augite, from the 'lattice' structure visible, and the latter serpentine.

No. $\frac{8}{846}$ is a plagioclase rock with micro-crystalline ground-mass, and porphyritic crystals of felspar and quartz present in it. The rock is much changed and bleached. It contains yellow epidote in irregular granules especially surrounding the porphyritic quartz grains.

No. $\frac{8}{847}$ was probably originally a diorite. It contains triclinic felspar, chalcedony in buff-coloured patches, green hornblende which in places seems to have become bleached to a colourless hornblende, remaining at the same time in optical continuity with the coloured part, green epidote in grains and micro-crystalline aggregates apparently derived from the decomposed felspar, and sphene.

Petrological Summary.

In the preceding pages we have found distinct evidence for—

(1) A metamorphic series, that is to say, a set of sedimentary rocks that have been variously metamorphosed; in some places only slightly so, and but thinly disguising their clastic origin and obvious position among the

historical strata; in other places highly metamorphosed and presenting all the characteristics of the most perfect crystalline schists. The question whether any of these are archæan remains open.

(2) A great intrusion of acid granitic magmas on an immense scale among the lowest sedimentary rocks, bringing about the metamorphism just referred to, and laying the foundations of the mountain backbone of the Himalaya and Hindu-Kush ranges. This acid magma there is evidence for believing to have been forced into the covering sedimentary rocks in Pre-Triassic times and in two ways: (*a*) leisurely, under no particular pressure probably, and without causing extreme metamorphic changes in those rocks; and (*b*) by an injective process, probably under enormous pressure, and bringing about a complete metamorphism of the strata and permeating them in a most perfect way.

(3) A subsequent mild intrusion of dykes of basic rock, which have cut through the Infra-Trias sedimentary rocks, through the schistose series, and through the gneissose-granite, without leaving exposed anywhere in Hazara known to me, any hemi-crystalline or glassy representatives of subaerial lava flows.

(4) The presence somewhere up the valley of the Indus river in at present unknown country of a more plutonic representative of these dyke rocks, namely, a coarsely crystalline granular rock shewing passage forms strictly analogous to those of the dyke series in Hazara.

(5) The presence also in that unknown country of an ultra-basic division of rocks and some serpentinised varieties.

(6) A wonderfully complete dynamic metamorphism of all the series of crystalline and metamorphic rocks, wherever palpable evidence could be gathered; which

has brought about a crushing, foliation, and recrystallisation of the rock components along certain lines, and especially at the margins of beds where rocks of different character adjoin, and where in consequence relief movements would be expected. The fact that these effects are strictly alike in the sedimentary rocks (conglomerates and quartzites) and in the crystalline rocks, makes it certain that the crushing and re-arrangement of the latter into separate mineral folia was truly due to dynamic causes acting on the rock in its cooled and solid state.

CHAPTER III.—DESCRIPTIVE GEOLOGY.

Disturbance zones in general.

Division of Hazara into convenient zones of disturbance.

A prominent structural feature of Hazara, as of most areas fringing the great northern watershed of India, is its easy division, for the purposes of description, into zones of disturbance, or elongated blocks of formations which lie parallel to the general strike of the country, and appear to have been driven to take up a characteristic position of their own by N. W.—S. E. tangential earth stresses. Without trenching on matter for discussion in a later chapter (general remarks), it will tend to greater clearness if for the time being it be assumed that each of these zones has an individuality of its own, marked (1) by the prevalence at the general surface of the country in that zone of some particular formation, (2) by geotectonic features due to earth movements that have been more or less limited in that zone to a particular period in the geological evolution of Hazarà.

Zones of disturbance classified.

These zones of disturbance are of various importance and grade, but certain of the larger and more comprehensive ones—although they may severally include minor disturbance zones — are as given in the next paragraph.

They will be made use of as a basis for the classification of the descriptive portion of this Memoir.

N. N. W.

(A) Crystalline and metamorphic zone.

(B) Slate, or Abbottabad zone.

(C) Nummulitic zone.

(D) Upper Tertiary zone.

S. S. E.

(A) *Crystalline and metamorphic zone.*—This is co-extensive with the whole of the northern parts of Hazara, including Khagan and the Black Mountain. There is also reason to believe that it has a much greater extension in a northerly direction, beyond where geological investigations have been carried. Its southern limits are well defined by a line running from Jutti Pind, 1,725 feet, up the Miankhaki stream *viâ* Sobruh Gulee to Puswal mian, and from there *viâ* Turnawaee and Dubbun to Gurhee-Hubeebooluh on the Koonhar. This line may be (*a*) a single well-marked reversed fault, (*b*) a plexus of faults, (*c*) a line of great equivalent folding of strata. S. W. of Jutti Pind there is no sharp southern boundary to this zone, but instead a gradual passage from slates to crystalline schists.

(B) *Slate, or Abbottabad zone.*—This zone adjoins the previous zone on its southern side, and it extends southward as far as a line running from near Bureeluh *viâ* Naruh and Kalabagh to Puttun Chhothee, a line easily recognised on the map by the remarkably continuous fault which follows it the whole way, and by the sudden appearance of Nummulitic limestone in force to the south.

(C) *Nummulitic zone.*—South of the last and adjoining it comes the third zone, which extends southwards to the Rawalpindi plateau in the south-west parts of Hazara, and to a line from Baroha *viâ* Tret, the gap N. of Kuldana hill, and Bukot to near Chhothee Puttun at the junction of the Koonhar and Jhelum rivers, in the south-east parts of Hazara.

(D) *Upper Tertiary zone.*—This embraces everything in Hazara to the south of the last zone, and it also extends far away

to the south across the Rawalpindi plateau, and hence out of the limits of this Memoir.

It will be convenient to begin with the description of zone (B), because in the first place it is the most characteristic and diverse in feature and formation, secondly the older geological investigators began in this part of the country, and thirdly by means of it, and it alone, can we be in a position to follow a description of zone (A).

(B) THE SLATE ZONE.

Orography.

General remarks.

The boundaries of this zone have already been defined. If the map be consulted it will be seen that they coincide with natural geological lines, inasmuch as the great schistose and gneissose area lies to the north, and the great Nummulitic area to the south of this zone. As the name implies, this block of formations is characterised by the preponderating presence of the Slate series. The later outcrops over a very large portion of it, and in many cases occupies a greater surface than do the younger formations of the same zone, whilst in nearly all cases it constitutes the lowest horizon that can be detected in the cores or axes of anticlinal or folded flexures. On the other hand, such flexures, on however grand a scale, never reveal any crystalline gneissose rocks below, and only in one or two limited localities have the lowest exposed strata assumed a slightly schistose aspect.

It follows as a corollary to the above that the younger formations present in this zone, from the Trias to the Nummulitic, are chiefly found as outliers, often on the crests of ridges only, or as long thin lenticular strips let in by sharp folding among the slaty basis of the zone. Their extension is generally a broken one, both along the strike and at right angles to it, though they are occasionally packed closely together with a nearly vertical lie like books on a shelf—a condition in which all traces of the original folds that brought about this state are completely lost.

The great diversity of formation in this disturbance block (which

is more marked than in any of the others) has a counterpart in the great diversity of surface feature, a few remarks about which will now be made.

Certain parts of the zone which have been cut down by denudation as far as the slates are occupied by recent accumulations of gravels, forming plains. The Abbottabad plain, the plain of the Dore river between Dhumtour and Turbela, and the plain of the Hurroh river in part are such; and these open cultivated areas leading from elevations of about 1,000 feet to 4,000 feet above the sea, form a natural highway from the lower levels, coinciding with the Rawalpindi plateau up into the heart of the district.

If we enter Hazara by leaving the railway at Hassan Abdal and taking the tonga[1] to Hureepoor we shall find ourselves in a great plain in the centre of the Slate zone. Standing on a turret of the old fort of Huree Singh at Hureepoor, our view all round is almost confined to a part of this zone. To the south-west in close proximity lies the native town, its busy thoroughfares and lines of mud-built flat-roofed shops contrasting with the quiet gardens of mango, loquortz, plantain, etc., which cluster round the town; and which fed with runnels of water from the canals offer cool retreats in the hot weather when round about outside the vertical sun beats continuously down on the blinding dusty roads. Beyond the town and beyond the gardens stretches the fertile plain of the Dore river and some affluents of the Hurroh river, bright green in spring when the wheat crop covers the land and yellow in autumn with the tall Indian-corn. This is a rich tract of alluvium, intersected by a complicated, if primitive, irrigation system from the Dore river, without which the plain would be nothing better than a sandy waste. The valley of the Dore, which may be seen stretching away to the east, is almost entirely restricted to the Slate zone. The river-bed itself, like that of most Himalayan rivers, is a wilderness of white boulders, half a mile wide, and from 100 to 300 ft. below the general level of the alluvial plain, which is cut off from the river-bed by sheer cliffs of gravel and sand. The stream

1 Tonga = mail-cart.

of the Dore is normally a tiny rivulet that can be crossed on stepping-stones, but it is subject to rapid spates after a rain-storm of any importance. The turbid brown or milky rush of water (according as it is fed from the nearer hills or the melting of snow from the higher crests) which then ensues makes the crossing of it, on a dark and stormy night, a matter of some anxiety. The leaping muddy stream rolls huge boulders along the bottom, which strike one another with dull thuds; and altogether it more nearly resembles the midday torrent from a large glacier than an ordinary rivulet. The circumstances which bring this about are chiefly the steep gradient of the river-bed, and the bare nature of the slate hills, which are the gathering ground near by, and which, for want of vegetation, have no power of temporarily holding the water. The view given in plate 9 of Sirban hill from the south includes a large portion of the river-bed of the Dore and shews the steep gravel cliffs which bound it. In many places several terraces rise one behind the other above the present level of the river, and mark out previous old channels of the same. Nearly all the streams and smaller rivers of Hazara are liable to be suddenly flooded in this way, but the Dore is more particularly addicted to it and more violent than the rest.

A few large villages such as Dhumtour, Rujoeeuh, and Huveliyan lie along the course of the river and typify the wealth of the alluvial country. Flat roofs and rubble masonry with narrow shut-in alleys and an abomination of filth make them unpleasant to the susceptible western nose. No tree has been left for shade, with the exception of the "Kao" or wild olive, a grove of which in nearly every village marks the graveyard; its sombre green contrasting with the bright verdure of an undergrowth of *Justitia adhatoda*. Water-power to grind the produce of the crops is supplied by the river, and abundantly utilised by an ingenious system of water-mills in tiers one above another which border the stream at intervals, their places being generally marked by a few willow trees.

In a south and south-easterly direction from Hureepoor the alluvial plain is much cut up by winding and deep nullahs which join the Dore and Hurroh rivets. Some of these pursue a most intricate course and resemble those of the Khuddera south of Rawalpindi. They all have their source in the slate hills lying further to the south. These slate hills first catch our eye as they rise out of the plain in the form of long rows or chains of tiny hills or even hillocks, all of which, by their N. E. by E. alignment, sound the key-note of the structural geology of Hazara, inasmuch as their direction coincides with the general 'strike' of the country. One very marked chain of hills embraces the summits known on the map as Dore 1,880 feet, Butta 2,058 feet, and Pudani 2,528 feet.

Still further to the south we may see from our vantage point that these previously isolated little ridges now merge together into the slate hill-mass lying N. E. of Bureeluh, and which trends away N. E. by E. in a closely packed set of minor ridges parallel to the course of the Dore. These hills, as can partly be made out even from a distance, are characterised by a great monotony of outline, by flowing rounded shapes and by an almost complete bareness of vegetation. Their dreary and dark hill-sides of slate, only beautiful when sunrise or sunset gilds their barren slopes, and the early morning mist brings out their purple tones, are here and there relieved by an occasional craggy crest caused by the few thin bands of limestone interbedded with them. Although further to the north-east there gradually set in some of the deeply inlaid faulted synclinals of the younger series of rocks, they have to continue for some way before they become of sufficient importance to exercise a dominating effect on the landscape. On the southern slopes of this low range of slate hills, where they face and abut against the Nummulitic limestone zone (next to be described), the same treeless and lifeless surfaces are the rule, for not only is there a lack of timber but also very few shrubs, and scarcely any grass. Only in a few places, as at Ghurukee and near Lunguriyal, are there a few Chir trees, *Pinus longifolia*, Khair, *Acacia*

catechu, Daranni? wild olive, *Olea europea*, and mulberry, *Morus alba*, whilst the hill spurs are partly clothed with Sumbal? and *Justitia adhatoda*. The water on this side is all shed southwards towards the Hurroh river and the streams have cut down their channel deeply into the slates. The whole of these slate hills from their S. W. extremity where they die away under the alluvium to the neighbourhood of Huveliyan, present the same monotonous features.

From our outlook on Hureepoor fort in a westerly direction we may see the gently sloping alluvial flat stretching away for ten miles and then ending abruptly in the high scarped edge of the Gundgurh range. That range, mainly composed of slates and schistose slates, has nevertheless a backbone of stout limestone, which gives it the regular and ideal aspect of a small hill range. For the same reason it rises to a considerable height above the plain. Its scarped edge facing us is bare of vegetation and has but little water. Beyond this range flows the changeful and rapid current of the Indus, and a short distance beyond that comes the north-west frontier of the empire.

Eastwards from Hureepoor on the north side of the valley of the Dore we see the near end of a long low range, composed entirely of slates without even any limestone bands to vary its uniform aspect. It continues E.N.E. up to and beyond Abbottabad.

At Hureepoor then we first find ourselves among the plains and hills of Hazara, and the outlook, though tame and devoid of the grander features of a mountain tract, brings before us very clearly the general surface aspect of the Slate series, the most ancient of any in Hazara; and illustrates early, even among these much-worn and sculptured remnants of a great formation, how dominating an effect the folding of the rocks has had upon the three hill ranges before us and the minor chains of hillocks, inasmuch as they all follow the direction of the axes of the folds, that is to say, generally with the geological strike of the country.

Continuing in the Slate zone in the direction of Abbottabad, and

rising gradually as we go along the plateau of the Dore with a gradient of 1 in 66, we find the panorama changing, and the sombre rows of hills on each side of us opening to admit wedges of younger rocks with their picturesque limestone crags or tumbled rocky slopes. Beyond Sultanpoor the valley before us divides, the main branch follows up the course of the Dore, whilst the smaller and steeper one leads over a low divide into the Abbottabad plain. Between the two rises the shapely form of Sirban hill, 6,240 feet. It is of the type known to mountaineers as the "writing-desk," though it is a complicated variety of it. Towards the north it offers a long, steep, and flowing dip slope, and towards the south an array of scarped crags and precipitous falls and ledges of rock. It is classical ground to the geologist, for here Dr. Albert Verchère some thirty years ago plied the first geological hammer Hazara knew, and he was followed by Dr. Waagen and Mr. Wynne, who made a special study of this hill-mass. It also possesses a few historical associations, common rumour crediting a cave under its summit with containing buried treasure belonging to Ranjit Singh; whilst it doubtless formed a good point of espial during the progress of the loot-gathering Dourani rulers and in the later Sikh times.

At the northern foot of Sirban lies the flat upland valley of Abbottabad at a level of 4,000 feet. It is a fertile oasis, between the rocky heights of Sirban and the low undulating slate hills further north. Abbottabad is the head-quarters of the Punjab Frontier Force, and has been referred to by a recent writer "as one of the workshops the like of which have fashioned and are fashioning the British Empire."

The sound of the bugle, the midday gun, and the screaming of transport mules mark the flight of the hours, whilst the parade-ground, the rifle-range, and the rocky hill-sides are seldom empty of troops at drill, at rifle practice, or engaged in mimic battle. A picture of this cantonment would be incomplete without the sturdy supple Gurkha, the fine stalwart Sikh, and the mobile mule battery at work or play among the green valleys and narrow hill-tracks.

The gently undulating surface of the station in spring and summer is bountifully covered with green grass, and the bungalows of the residents peep out from among gardens rich in shade trees and orchards, the latter including apricot, quince, peach, plum, pear, cherry, and the grape vine. The hedge-rows and-gardens are adorned with roses and other flowers, whilst buttercups and dandelions deck the grass.[1]

This park-like almost English beauty of Abbottabad in the spring-time never fails to strike the new-comer in contrast to the bare and dust-coloured panorama of the low country of the Punjab.

The Abbottabad plain merges north-eastwards into the Mansehruh plain, whilst towards the east it rounds the north end of Sirban hill and descends rapidly, but gradually, to the level of the gravel terraces of the Dore near Dhumtour. Thus from the level of Abbottabad, 4,000 feet, to Turbela on the Indus, 1,200 feet, the disposition of the gravel and alluvium forming what appear to be flat plains is really, as has already been explained, that of a uniform slope with a curve concave towards the sky, and with a regular diminishing steepness towards the lower level.

North-east of the Abbottabad plain the Slate zone grows in height, steepness, and ruggedness. The great geological complex near Meerpoor, Kakool, Turnawaee, Dubbun, and Gurhee-Hubeeb-ooluh has resulted in a surface of rocky steeply-carved ridges and ravines, difficult of access, and most of them connected in an irregular way with the great Tandíani mountain-mass and its northern and western offshoots. But here, as elsewhere in this zone, it is not difficult to trace out the prevailing direction and parallelism of ridges as according with that of the strike of the country, that is about N.E.—S.W. At the same time the main watershed, consisting of a number of high peaks with gaps or passes between them and stretching from Sichar peak, 8,645 feet, to Mianjani, 9,793 feet, crosses this direction almost at right angles, and is often spoken of as a ridge, and

[1] Why fruit trees are not introduced throughout the plains of Hazara, now that the country enjoys complete peace, instead of the latter depending almost entirely for fruit on Kashmir, has always been a puzzle to me.

represented on small-scale maps as a continuous ridge. The grander scale and height of these hill-sides introduce a more temperate flora, the zone from 6,000 feet to 8,000 feet and upwards being covered in parts with north temperate coniferous trees, and with oak, chestnut, elm and maple, often of fine dimensions, but not reaching the same perfection that they do in the "gulees" of the Nummulitic zone, to which reference will be made in due course. The slate formation itself, on account of the hard beds of quartzite which are inter-stratified, rises sometimes to great heights as at Mianjani and Taumi. Tandíani is a hill station of a few wooden houses used as a summer resort by the Abbottabad residents and others, but in the winter months it and the rest of the higher ridges and peaks are a desolation of snow and sombre conifers, the snow often lying on suitable shady slopes up to the month of June.

West of this mass of peaks and ridges come the semi-detached masses of Bunyan hill, about 6,000 ft., Taumi, 8,025 ft., and Tope, 6,645 ft., with their side ridges and spurs trending N.E. and S.W., and in the latter direction lowering gradually till they merge into the low slate hills south of the Dore river near Rujoeeuh.

These rocky thickly wooded mountain-crests averaging 6,000 ft., with a keen cold bracing air blowing round them, descend sharply and steeply to levels of 5,000 and 4,000 ft.; at which levels the slopes swell out into broad foundations which are dotted with small hamlets and covered with terraced fields, the retaining walls and banks of which seen from a distance look like a natural system of approximate contours drawn on the earth itself. They descend downwards to the level of the gravel terraces which further broaden out the base of the slopes. Below this again the same terraces are deeply cut into by water-channels, and present steep disintegrating precipices bordering the edges of narrow winding gorges where the ever-murmuring streams, out of sight from above, continue their work of erosion.

On the eastern side of the Tandíani-Mianjani watershed the level of the country descends very rapidly. All the formations above the

Slate series end, and the latter occupies the whole of the great bare monotonous tract between that watershed and the Koonhar river. Villages like Chhothee Puttun, placed on comparatively flat or gently sloping spurs, are surrounded by convex slopes of disintegrating slate, whose ever-increasing steepness at last ends in the closely-shut-in gorges that drain eastwards into the Koonhar river.

The Koonhar river itself which taps the snow-fields of the Khagan valley is of the nature of a profound gorge with a very winding and very steep river-bed.

Descriptive detail,—general remarks.

In writing up the descriptive part of a memoir such as this, there are two dangers into which one may fall—one may say too much and one may say too little. To bring forward exactly the right amount of proof in the form of actual traverses to establish a given bit of geological structure is a golden mean of which it is not always easy to avail oneself.

Hazara is a district in which roads from one place to another follow no general direction or rule. From any one point the geologist may start in any one of a great many radial directions following native-made paths which go from village to village. The large number of traverses and counter-traverses which have thus been made by myself and party would, if given as recorded in my note-books, be tiresome and confusing; many of them, as is but natural, have proved of little use, whilst others merely repeat sections better exposed elsewhere. On the other hand, it is equally necessary that sections of some sort should be described—sections which must include several formations, for the country is so complicated in detail that to take any one formation and to describe it from beginning to end, and then to take another and do likewise, disentangling each and laying them out straight before the reader, would not only cause endless repetition but would defeat the object of this chapter, which is to show the formations, not as individuals, but as corporate members of one structural whole.

It follows, therefore, that the sections which I shall now describe will be more or less artificially selected ones. They will not be limited in the same way that the actual traverses over the ground were limited by accidents of time and opportunity, but they will in many cases embody results of two, three, or more separate traverses, which may have been undertaken consecutively or at broken periods of time. By this means much space and weary confusing details will be saved.

Sections round about Hureepoor.

Within a day's march of Hureepoor we can examine several sample sections in the slate formation. We can visit the hills to the south, east, or north-west, and traverse large areas of slate without coming upon anything higher than Infra-Trias. We will first of all examine the low hills to the south-east of Hureepoor, after having crossed over the flat plain of recent gravel and alluvium that stretches between these places.

Near Bandee Sher Khan we reach the first of the little bare strike ridges made up of slates. From that point across the hills to the south up to the edge of the Nummulitic zone the slates are set at steep angles with cleavage and bedding generally coinciding, but not always, as can be seen by the parallelism of the former with the interbedded limestones. The special feature about the slate formation in this part of the country is these limestone bands which seem to be interbedded with the slates. On the map several of them are shewn, though the thickness there represented is considerably in excess of their real thickness. Throughout this area we may remark the very steady strike of the slates. This is manifest in several ways, *viz.*, (1) by the cleavage and bedding of the slates, (2) by the connected chains of little hills which mark outcrops of the harder bands of more quartzose material in the slates, (3) by the interbedded limestone bands which can be seen capping the crest of one little hill after another, especially in the neighbourhood of Peer Kot. With this regularity of strike there is a

regularity of dip in one of two directions, but in amount and absolute direction the evidence offered by the imperfect sections exposed is not conclusive. The general impression that one gets in studying the section is that there is considerable folding and contortion of the strata, a view that is borne out by the repetition of the limestone bands of the nature of the Lunguryal band, one of which is seen at Bandee Sher Khan, and others along several lines between that village and the watershed. The band at Busera resembles the one found at Phoolah Gulee in an uncertain way, both being slightly metamorphosed with a faint marble-like aspect. The rest of the bands all resemble the Lunguryal band which has been described in the chapter devoted to the petrology of the stratigraphical elements.

Besides the evidence of repetition of these bands, the dips are high wherever actual sections are well exposed, as, for instance, along the road near Phoolah Gulee. North of this place there is a massive dip of some quartzose varieties of the Slate series (which is probably a real dip) in a north-westerly direction.

It will be seen that two of the limestone bands referred to above die out about the position of Maira Turla. This dying out seems to be by loss of material—a gradual process of thinning out, though it might have been partially effected by the continuation in that direction of the Naruh fault (see Nummulitic zone). North-east of Maira Turla there are no more instances of limestone bands interbedded with the slates; but to the north-west, in the Gundgurh range, as we shall see, they attain very great individual thicknesses.

Sirban hill sections.

Leaving the simple aspects of the Slate zone, as evidenced near Hureepoor, we will now examine the Sirban hill. On account of its classical associations in the history of geological investigations in this part of the Panjab, I propose to treat it more fully than I should otherwise do. Moreover, in consequence of its epitomising much of the geology of Hazara we shall gain something by examining it minutely as a type of much that will follow. Dr. Waagan and Mr. Wynne have described this hill in considerable detail in their joint

memoir. I was early attracted to it as being a most accessible and typical part of Hazara. I must here state that in the descriptions which follow, my indebtedness to Waagen and Wynne will be apparent on every page to all who have read their joint paper. Here and elsewhere I have endeavoured to follow their lead as regards their classification and interpretation of the rock structure, and have only departed from it when obliged to by very decisive facts.

Sirban hill has already been said to be a bold massive hill feature of the "writing-desk" kind, rising steeply from the alluvial country round about. Its aspect from the north and from the south-east can be gathered from the views (Pl. 6 and 9).

To describe the geology of Sirban in a few words is scarcely possible, and I must ask the reader's patience whilst I take him from one point to another in a somewhat erratic manner, for only by so doing can I put the matter before him in a clear and consistent way.

Tanakki glen.

We will begin by visiting the little shut-in glen with amphitheatre-like crags all round it in the neighbourhood of Tanakki. There we have exposed the lowest formation, namely, the slate series. Only in this valley and along the south-eastern margin of the Sirban hill-mass do the slates emerge normally from beneath their great load of overlying limestones (Infra-Trias to Nummulitic, inclusive). The Tanakki glen may be looked upon as a rough anticlinal in the rocks above the slates, open towards the south-west by the glen spreading away into the alluvial flat of the Dore river, and arched over towards the north-east, not by a regular unbroken anticlinal of Infra-Trias, etc., but by an irregular arch broken by the tail end of the great north Sirban fault (see on) on its northern side, and by a sharp reversed fold accompanied by a huge dislocation on its southern side. The slates keep a low position in the valley and present no features different from those described under the heading of Petrology, except that there are no interbedded limestones. The varying amount of sandy material mixed with the more argillaceous slates makes it an easy matter

to deterimine the true dip which is of the usual high amounts, much obscured in places by surface deflection, but giving in general a dip of 40°—60° S.E. or S.S.E. This is especially marked in the vicinity of Koti-ki-khubbur, where the road from Berwal joins the Hureepoor-Abbottabad road, five miles from Abbottabad.

Here the basal conglomerate of the Infra-Trias is best seen in its unconformable position above the slates. This unconformity is one of the most important geological features of Hazara. It admits of no doubt, and we are thus early introduced to that sharp line of division separating everything that is above it from the great Slate series beneath.

The Infra-Trias is ushered in by this conglomerate, and it needs but a glance at the great crags which form the ridge north of Tanakki to see that they—composed of an ascending series of sandstones, quartzites, and limestones, coming above the conglomerate—are dipping *en masse* in an exactly contrary direction to the slates. Besides this, very many of the exposures on the hill slope individually shew the over-stepping of the conglomerate across the truncated edges of the Slate series.

The nature of this conglomerate has already been described. It is sufficient here to remark that its character and obviously derived origin from the rocks immediately beneath tend to strengthen the conclusion as regards the profound stratigraphical break indicated by it. It is not difficult to follow this conglomerate round in a north-easterly direction for some way up the Tanakki glen; but due north of Tanakki it is generally hidden locally by débris from the crags above, or by slip faults in part connected with the great north Sirban fault. The purple shales follow in normal sequence above, and these in turn give way to the deep purple sandstone. They in turn pass by a lithological transition into similarly coloured limestones which higher up become flesh-pink and then white. All these belong to the Infra-Trias group, a very fine section of which is to be found above Tanakki by ascending a cleft or gully in the precipitous crags north of that place. The ascent is easy.

A prominent distinction between the Slate series and the conglomeratic and shaley portions of the Infra-Trias in this locality is that the latter shew no trace of any cleavage, whilst the individual pebbles of which the conglomerate is made up each possess in this locality the cleavage of the parent rock from which they were derived. In view of other sections to the north of this where the conglomerate has a cross-orientation of the long axes of the pebbles (as in the Cambrian conglomerate of Snowdon) and a cleaved matrix, this point is of considerable importance and will be referred to again.

When the top of the crags is gained the whole of the bare north face of this part of the Sirban mass is seen to be sheeted by these limestones which possess singularly marked and characteristic features. They weather into a very white coloured rook, which is sometimes vesicular, and generally banded throughout by layers of chert. The joint planes are prominently developed, and appear as if made in some soft material like wood by criss-cross strokes from a heavy sharp implement. There are a few bands of coarse white grit or quartzite.

It will be seen by reference to Waagen and Wynne's map and figure 4, page 15, of their Memoir on the geology of Sirban, that these rocks are represented as Infra-Trias only up to a certain line running east of Mehra village, beyond which the greater part of the north face of Sirban is classed with the Trias formation. In the course of mapping this hill I found no reason whatever for this arbitrary line of division, and good reasons both lithological and structural for the alterations I have been compelled to make in the mapping of this part.

As this will be found to be the greatest point of difference between myself and Mr. Wynne in the mapping of Hazara, it is perhaps necessary to explain my reasons for a change that makes a large alteration in the geological features of Sirban. They are :—

(1) All these limestones which sheet the hill-side are always found (when they are found at all) in normal order superposed on the top of the typical Infra-Trias (conglomerate, shales, sandstone, and deep purple limestone). On the other hand, they are never found

beneath the typical Trias limestone when those lower members of the Infra-Trias are absent as well. This generalisation does not merely apply to the Sirban hill sections, but to all the sections in Hazara. These facts indicate that those limestones are one with the arenaceous and conglomeratic portion of the Infra-Trias series, and, though not always present when the latter are present, are always absent when they are absent.

(2) If we traverse down the slope from the ridge north of Tanakki and cross the stream-bed east of Mehra, keeping a line north or north-north-west so as to get well among the lower portions of the exposed strata, we shall see that there is no line of division whatever between a formation that can be classed with the Infra-Trias and another that can be classed with the Trias, along the line indicated by Waagen and Wynne. The sequence is continuous lithologically and structurally, and we simply cross beds of typical white Infra-Trias limestone with the vesicular and cherty structures mentioned above and with the interbedded sandstones, all dipping uniformly down the slope at 40°-45°. There is no trace of the hæmatitic felsite which is the basement bed of the Trias, nor is there anything which lithologically resembles the ordinary Trias limestone as found generally in Hazara. Only when we come to the beds marked as Tagling by Waagen and Wynne do we come to what I regard as true Trias.

The beds marked *a*, *b*, *c*, *d*, by Waagen and Wynne in their memoir, figure 4, page 15, index references to which will be found at page 17, require, therefore, to be placed with the Infra-Trias limestone, as they certainly belong to a series which really underlies the hæmatitic breccia and felsitic rock. Bed *b*, is, however, said to contain fossils, *pecten*, etc., a point I was unable to verify. The source of the error in their figure 4, page 15, is to be found in the misconception that the bed marked *x* (hæmatitic breccia) present on the summit of Sirban belonged to a horizon beneath *a*, although they failed to find it in this place. Its horizon is really beneath the bed marked *e* by them in the same section, although not visible there probably by reason of a

small fault (obviously had the hæmatitic rock appeared in its normal position here beneath *e*, this misconception would not have arisen). The same error has been repeated in the section, figure 3, page 15, where the hæmatitic breccia is represented as passing through the middle of the Trias series. This anomaly, which puzzled Waagen and Wynne (see page 17 of their memoir), does not really exist. There is no trace of the felsite in the stream-bed section south-east of Sulhud as far as I could see. It is true the bed is present on the top of Sirban, and if the stratification of the limestone-cliffs be followed from the summit down into the glen, the bed *x* would come at about this horizon if it were really interstratified with them; but its unconformable position on the top of the Infra-Trias beds carries it completely over the dip-slope on the northern face of Sirban in the neighbourhood of Sulhud. It is caught again in a small fold further to the north-east near Abbottabad, as will be made evident in the section now to be described.

The difficulties and anomalies of the Trias sections mentioned by Wynne and Waagen at page 10 of their memoir alike vanish under this interpretation.

Sections east-north-east of Sulhud.

If we travel along the road from Sulhud to Abbottabad, we shall find the great dip planes of the Infra-Trias gradually subsiding into a gentle or almost horizontal condition near the foot of the mountain. The road winds round the base of scarps and cliffs of this very characteristic rock. If we stop on getting to the outskirts of Abbottabad near the new Octroi office, we see the limestone standing up in horizontally bedded bluffs, with a depression behind on the higher mountain slope. This depression is the trough of a synclinal, and in it we shall find very characteristic exposures of the felsitic rock of Sirban (see view of Sirban from the north, Pl. 6).

Sections near Abbottabad.

On the near hill-side in the view of Sirban from the north, we have the following section :—At the base the Infra-Trias is bent into a gentle synclinal, shewing innumerable bands of the cherty material parallel to the bedding.

These increase near the felsite above; and it does not seem improbable that they have some connection with the felsite (*e.g.*, are the result of contact metamorphism). Above the limestone come two or three beds of the felsite, very distinctly banded and with what I regard as flow-brecciation structure very visible. It is of various colours, from grey to purple or dark green. The thickness of these is not very great, not more than 30 feet. Above them in turn comes a quantity of shales, some of which are purple and micaceous, and others of a buff colour and entirely resembling those at the base of the Trias near Sulhud, called Tagling by Waagen and Wynne. In the upper part of the brecciated felsite there occurs hæmatitic material, making its appearance as a sort of ground-mass in which the broken-up pieces of felsite are scattered.

This felsitic and hæmatitic rock may be followed in one direction up to the top of the little hill marked by two trees in the view of Sirban from the north (Pl. 6), where it gradually assumes the steep dip of the underlying Infra-Trias limestone. It is bounded on the east by the north-eastern end of the north Sirban fault, which takes it underneath the cliffs of genuine Trias limestone. In its position on the two-tree hill it is exactly analogous to the same rock on the top of Sirban hill: it has been left as a skin on the north face of the two-tree hill and then caught in the synclinal as described, whereas in the case of the north face of Sirban it has been denuded away in all the lower parts of the mountain.

The Infra-Trias limestone, with this single interruption of the felsite and hæmatite, continues to occupy the northern aspect of the Sirban massif as a much-contracted sub-zone up to Shakur Bandee village. It is then lost under the alluvium of the Abbottabad plain, to reappear again in the direction of Kakool. From the point on the ridge near Shakur Bandee the great north Sirban fault is still its limit in a south-easterly direction.

It will now be convenient to cross this sub-zone boundary fault and see what is the condition of things on the other side. The first and most important thing noticeable is that the Trias limestone is

generally in contact with the fault on that side. It would not be easy to mistake this limestone for anything else. It possesses all the characteristics of the typical Trias, that is to say, it is of dark somewhat purplish-grey colour, sometimes finely oolitic and sandy. It shews the blotches of ochre colour in many places, and never throughout its whole thickness has the slightest resemblance to the rocks on the north-west face of Sirban, which I have sought to establish as belonging to the Infra-Trias series.

In the low part of the ridge near Shakur Bandee the Trias dips down against the fault at a high angle. Further to the south-west the little spur, running north-west in a line with Abbottabad in the view of Sirban from the north, shews a much more gentle roll up against the fault, which can be plainly seen cutting off the Infra-Trias at the lower end of the hill-spur. In the vicinity of two-tree

Two-tree hill.

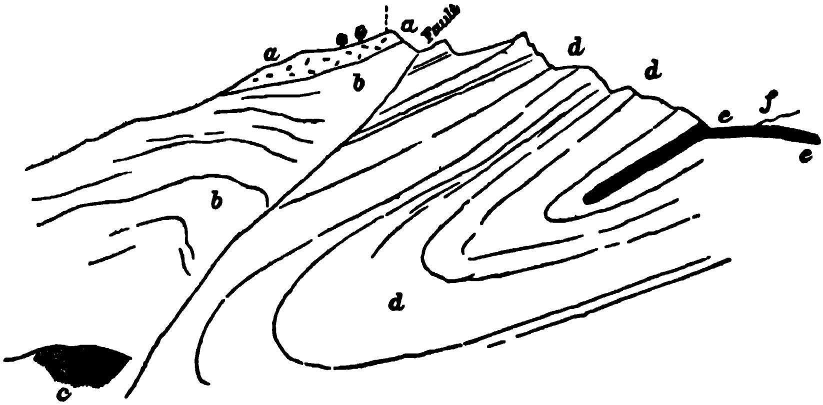


Fig. 6.

c—Purple sandstone.
b—Limestone and quartzite. } Infra-Trias.
a—Brecciated felsite.
d—Trias limestone.
e—Spiti Shales.
f—Nummulitic limestone.

hill, both north-east and south-west of it in the neighbouring glens, the position of the Trias against the Infra-Trias is a good example of a sigmaflexure with broken middle limb. In figure 6 I have sketched a view of this, as seen from near the head of the glen running north-west to Sulhud. The middle limb of the inverted fold has given way rather on its northern side, thus leaving much of the trough of the fold in the Trias intact. The sharpness of the inversion may be imagined from the narrow compressed position of the Spiti shales which occupy the axis of the trough. On the north side of the fault we have a completely normal section down from the felsite through Infra-Trias limestone to the purple sandstone, which may be seen at one place as indicated in the figure. Looking south-west from the head of this glen under the mass of Sirban the same marked line of break between the Trias and Infra-Trias is visible, the scarped edges of the Trias being very prominent. The line of the fault makes an angle with the vertical somewhat greater than 30° and approaching 40°. This causes the Trias to V down into the stream-bed in a very decisive way. In the section, figure 3, page 15 of Waagen and Wynne's memoir the actual line of this junction appears to have been confounded with an ordinary dip plane. Hence the apparent underlie of ordinary Trias limestone beneath the Infra-Trias to the north, and the consequent misunderstanding as to the horizon of the latter. The fault admitted by Waagen and Wynne is placed some way to the south-east along the face of the scarp in the Trias limestone, where the strata are recovering from the dip down against the fault and passing under the peak north-east of Sirban. A comparison of their map with mine will make clear our points of difference.

The Trias band we are now considering may be very well studied along the spur going north-east from the two-tree hill. The sharp faulted boundary between it and the felsite is clearly seen in plan on the ridge by the way the bare strata of Trias are gradually truncated at a very acute angle by the felsite. This spur is scarped on its south-east side with a well-exposed section of Trias limestone. Near

the foot of this scarp in the stream-bed going towards Shakur Bandee the base of the Trias, with its Megalodon bed, shales, hæmatite, and brecciated felsite are seen directly superposed on the coarse white and purple quartzites which are easily recognised as identical with those near the base of the Infra-Trias. On both sides of the stream-bed the section is very distinctly exposed, the strata being thrown into a gentle arch at this point. Hæmatite is in considerable force, making a very rich ore in this valley and on the gap in the low ridge to the north-west. From this point its direction is alternately on the ridge, and on the north-west slope all the rest of the way to Shakur Bandee. Some of the brecciated felsite in the stream-bed is extremely beautiful. Although the basal conglomerate in the Infra-Trias is not exposed in this stream, the lithological characters of the purple and white arenaceous beds, and the entire accordance of this section with that to be presently described on the south-east side of the mountain near Bazdar where the conglomerate is present, fix the horizon of these beds beyond doubt. That being so, the absence of any Infra-Trias limestone in the section is at first rather startling in its significance, inasmuch as it implies a very rapid overlap of the base of the Trias across the edges of the Infra-Trias limestone; for the latter is well developed, as we have seen, half a mile to the north-west. Other sections on the south-east and south-west side of Sirban will, however, be seen to allay any uneasiness on this score (see on pages 108, 109). Incidentally it may be remarked that if we take into consideration the north Sirban fault, and allow for the folded and compressed condition of the strata from which that fault originated, the apparent suddenness of the lateral change indicated by this overlap is considerably diminished.

Sections near Mahmda, Bazdar, and the ridge east of Tanakki.

Before turning our attention to the younger rocks coming above the Trias it will be better to examine the sections mentioned in the margin as regards the inter-relations of the great Slate series, the Infra-Trias, and the Trias. At Bazdar (see Hor. Section No. I) under the crag of Trias limestone there is the hæmatite bed and a thin band of the

felsite lying directly upon the quartzites and sandstones of the Infra-Trias as in the Shakur Bandee glen, whilst beneath the deep purple and white banded quartzite come purple and greenish shales, and then the basal conglomerate in its unconformable position above the slate series. There is no Infra-Trias limestone in the section at this locality; but Babu Hira Lal drew my attention to lenticular bands of cherty material among the purple sandstones coming next beneath the felsite which had a great resemblance to the cherty bands in the limestone of the north face of Sirban. If we take it as plausible that these cherty layers have some connection with a contact metamorphism induced by the felsite, then the occurrence of this band in the quartzite is of considerable interest.

West of Bazdar and west of the deep ravine coming south-south-east down from the main peak of Sirban the hill-side exhibits a very instructive variation from that first given, inasmuch as between the purple and white sandstones and shales of the Infra-Trias there is present a bed of pink sandy limestone a few feet thick, which is followed by white quartzite and then by the felsite and hæmatite and Trias limestone. The pink limestone possesses the characteristics of the ordinary Infra-Trias limestone as seen on the north face of Sirban. Its peculiar way of weathering in particular is of the same nature as in the limestone sheeting the north face of Sirban.

If we mount the steep craggy ridge traversing the section across the edges of the Trias and the superposed Jurassic Spiti shales, with a very small amount of grey limestone (Nummulitic) above them, we are met by the huge dislocation referred to on page 128. It is a fold-fault of much the same kind as the north Sirban fault, but its extent is not so great. Immediately north of it the ridge joining the higher summit of Sirban with the 4,070 feet spur near Mahmda is peculiar in that the strike of the beds is almost north and south for a short distance. The beds represented show the Infra-Trias in force on the western face of the ridge with large thicknesses of the limestone above of the white kind with cherty bands. This is covered by the felsite and hæmatite, and that in turn immediately overlaid by

large thicknesses of the Trias limestone steeply dipping down the east face of the ridge for some way (or else inverted) and then thrown into great corrugations at the head of the glen under the beetling crags of the Sirban peak. At other places in this glen-bottom which opens towards Bazdar, where occur repetitions by faults and folds, as shewn Pl. 9 and Hor. section I, the Infra-Trias limestone is occasionally seen intervening between the Infra-Trias quartzite and the hæmatite; but as we descend the glen the limestone rapidly disappears from the section, until there is no trace of it, as already stated, at Bazdar.

The above section is interesting as definitely shewing a great series of the white cherty banded limestones, distinctly overlaid by the felsite and hæmatite (the latter being followed by the genuine ordinary Trias limestone) and distinctly underlaid by the sandy, shaley and conglomeratic portions of the Infra-Trias.

From the foregoing the relations of the Trias to the Infra-Trias would appear to be that of unconformity. Nevertheless, it may be worth while glancing at the situation in another light. A possible, if not probable, way of explaining it would be by assuming a rapid thinning-out of the Infra-Trias limestones in a south-easterly direction underneath the Trias. Let it be supposed that there was no original deposition of the limestone in this direction at all and see how it fits in with facts. There are certainly some aspects in which such an explanation would seem plausible enough, but the chief difficulty in the way is the short horizontal space available for such a fundamental change. Taking the thickness of the Infra-Trias limestone at its thickest as roughly approximating to 2,000 feet, it is necessary to imagine submarine conditions, whereby a deposit of this thickness was continuously laid down in one area with nothing to represent it in an adjoining area separated by not more than four miles (allowing for the compression of the region by folding and faulting). On the other side of the question the only evidence against the unconformity is:—(1) The absence of any eroded or irregular surface of the lower beds upon which the base of the Trias rests, and

(2) the apparent absence of the felsite and hæmatite beneath the Trias limestone in a north-easterly direction towards Dhumtour where the Infra-Trias is also absent. In this connection it may be also noted as peculiar that, beyond Kakool in the Turnawaee direction, the felsite and hæmatite are always present between the Infra-Trias and the Trias, but never present at the base of the Trias when all representatives of the Infra-Trias are absent.

The Jurassic, Cretaceous, and Nummulitic rocks of Sirban.

The north-easterly part of the Sirban hill-mass is chiefly composed of the great Nummulitic formation. The very top of the Sirban ridge itself, east of the 6,243 feet summit, is also crowned by an outlier of this formation. These two separated areas are shewn as one on Waagen and Wynne's map, whereas in reality the outlier on the top of the ridge is completely cut off by a band of Trias limestone as shewn on my map.

In this Sirban section as over a large part of Hazara the limits of the Nummulitic formation in a descending order are very plainly indicated by the characteristic appearance of the Jura-Cretaceous rocks at its base. The black shales known as the Spiti shales are very generally distinguishable either *in situ* or in the form of débris which has slipped down the slope or been washed by rain into the stream or torrent beds. The Spiti shales also make a marked break on the hill-sides in many places, as for instance on the slope east of the stream running north-east to Shakur Bandee, and near Shawali on the eastern side of the Sirban mass. Very often, too, the outcrop of the Spiti shales is marked by a line of springs as on the south-east side of the high ridge.

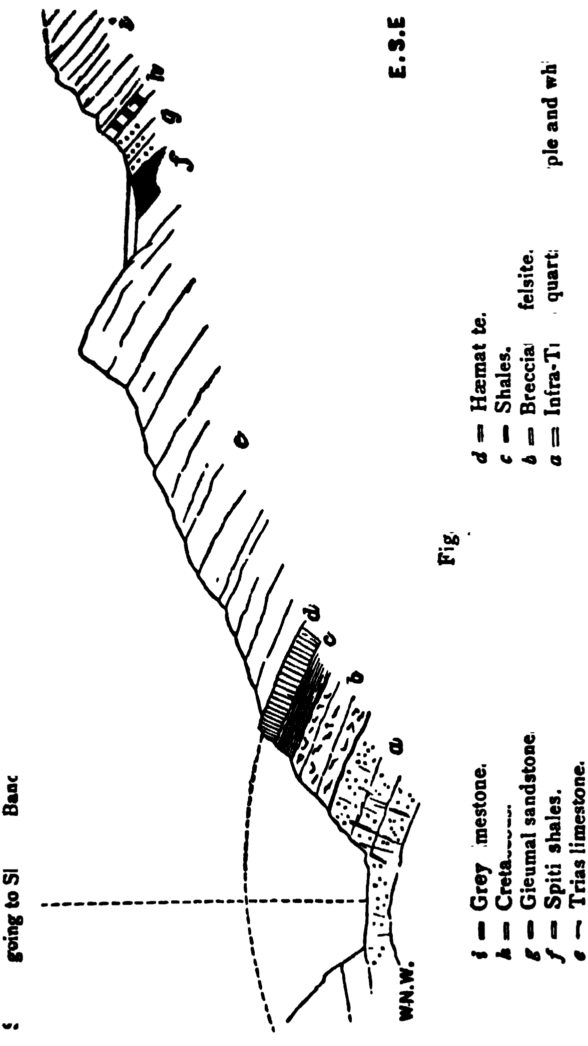
It is chiefly owing to these marked surface features of the Spiti shales and the Cretaceous band that the working out and mapping of much of the geology of Hazara has been rendered easier than it would otherwise have been; in especial the difficulty of distinguishing readily in the field the different members of the great limestone formations has thus been greatly reduced.

The section indicated in the margin gives a fair idea of the

general position which the younger rocks of the Sirban hill hold with regard to the general structure of the mass.

Section from Sulhud glen across the Sirban ridge through Nugukkee.

We will first consider the little outlier forming the top of the ridge. On the north-west side of the ridge the outcrop of the Jurassics is not a very clear and defined one. This portion of the hill-side forming the head of the glen going to Sulhud is much obscured by fields. But proceeding in the direction of the two-tree hill, or rather to the little gap to the south of it, where the north Sirban fault passes, we shall gradually find the outcrop becoming more distinct. At the point where it turns round towards the south-east face of Sirban the Spiti shales are well indicated by the presence of a copious spring of water (and a tree or two) which supplies the needs of the village on the top of the two-tree hill and other little hamlets near. On and near the pathway leading from the gap south-east of the 6,243 summit to Nugukkee we cross a continuation of the same Jura-Cretaceous band. It is here again marked by a spring of water, and the terraced fields all round are tinged a dark colour by the degradation of the shales. In all these outcrops of the Jura-Cretaceous there are apparently all the ordinary members of the sequence present, although there are many sections in other parts of Hazara which much better show the nature and relations of these rocks. The dark shales are, however, pretty generally visible, and the Gieumal sandstone may easily be detected in blocks strewn about the slope in the near vicinity of the shales, whilst the Cretaceous rock (always a thin band) can only with difficulty be found here and there in isolated blocks displaced from its *in situ* position. If we cross to the south side of the outlier we are now considering, following the pathway to Nugukkee, we shall see the Spiti shales lying on great bare surfaces of the Trias limestone; both of these formations being much puckered and sharply folded as the head of the glen going towards Bazdar is approached. In Horizontal Section No. I, I have indicated this puckering and contortion as the formations come within the influence of the north Sirban fault. Above the encircling outcrop of the Jura-



Cretaceous, the thin-bedded Grey limestone and possibly some of the Nummulite-bearing limestone also, form the rather steep and rough hill-side leading to the top of the ridge.

Leaving the higher parts and continuing on towards Nugukkee we cross a band of the Trias as an anticlinal, sharply reflexed, and then come upon all the Jura-Cretaceous and Nummulitic series again in a slightly inverted position. The Spiti shales here yielded some fairly perfect specimens of *ammonites* and *belemnites* collected by Hira Lal. This Jura-Cretaceous band continues north-north-east and joins up with the band in the glen going towards Shakur Bandee, where a marked depression in the hill-side (about the position of the word Ookhreeluh on the map) reveals its presence. The accompanying sketch-section shows its position and the rocks below and above.

The above is practically the section figured in Dr. Verchère's section (Journ. As. Soc., Bengal, Vol. XXXVI, p. 29, 1867) and rather unfairly animadverted upon by Wynne and Waagen in their memoir, p. 14; but he apparently did not detect the thin and somewhat obscured outcrop of the Spiti shales or Cretaceous. For some little way beyond this along the direction of the outcrop the Jura-Cretaceous can be followed by the depression at the surface alluded to above, but about 1 mile on this side of Shakur Bandee the débris from the Nummulitic cliffs have hidden the outcrop for the rest of the way. Returning back along the outcrop we might follow it in a S.S.W. direction across the hill spur going from Sirban to Bazdar, when we should see that it and the overlying nummulitic formation are not continued in this direction, and that the Jura-Cretaceous outcrop returns upon itself, following a devious course towards Dhumtour. The steep glen to the west of this spur is cut down through the Trias into the Infra-Trias, and there remain on the hill east of Tanakki only two small patches (scarcely representable on this scale map) of the Jurassic, Cretaceous and Nummulitic formations.

The steep crags of Nummulitic limestone with the strata vertical or reversed which come next the Jura-Cretaceous band on the pathway from Sirban to Nugukkee shew the usual characteristics of that series. The pathway zigzags down among its cliffs, which gradually lessen in steepness as the somewhat large village of Nugukkee is approached. Although the strata are still dipping in towards the hill-side, it is plain that we are ascending in the series, for shaley bands interstratified with the nodular limestone become more numerous. In one of the former quite close to Nugukkee and a little north of it there is a rich band of corals of the genus *Montlivaltia*. Nugukkee is placed on the chief beds of shale which make a somewhat flattened-out platform along the axis of the reversed synclinal. The platform is bounded on the south by a descending series of more of the harder Nummulitic limestone which there again presents a steep scarp down towards the valley of the Dore (see view of Sirban from the south).

Near the foot of the hill the base of the Nummulitics is reached and the Jura-Cretaceous is exposed with a fine development of Gieumal sandstone in which some fossils were found. The Cretaceous is not well seen as a distinct bed at this locality, and the Spiti shales are reduced to next to nothing, if not absolutely absent. Waagen and Wynne say there is no development of Spiti shales beyond in the direction of Dhumtour, but this is not strictly true, as further on towards Shawali they come in again, and the whole of the Jura-Cretaceous band forms a marked line of depression on the hill-side easily distinguished from a distance. At Shawali the hill-side presents the appearance sketched below :—

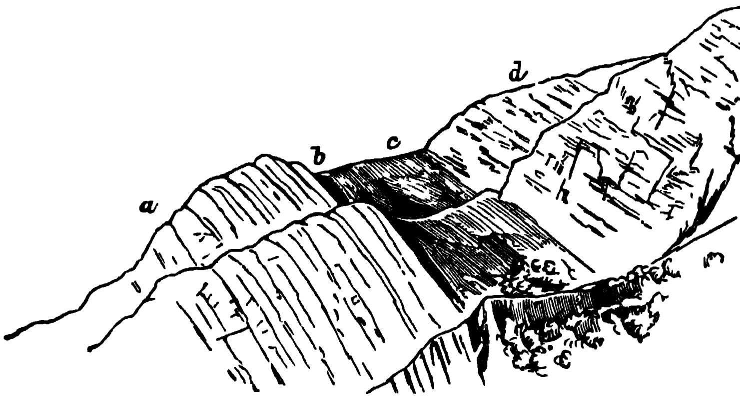


Fig. 8.

d = Grey limestone.
c = Gieumal sandstone.
b = Spiti shales
a = Trias.

In any case the statement of Waagen and Wynne (Sirban Memoir, p. 11) that the "cretaceous beds appear to follow immediately above the triassic limestone" is incorrect inasmuch as there is always present a certain thickness of Gieumal sandstone, even when the Spiti shales are not visible.

Section near Shawali.

The Gieumal sandstone which with its overlying Grey and Nummulitic limestone is quite close to the foot of the hill at this place (Nugukkee) can be seen to climb up the hill-side in the direction of Shawali. There is also some

considerable contortion of the statra well seen in the view (Pl. 9). The Trias limestone coming beneath it is of considerable thickness and is very typically developed. About 1½ miles before reaching Shawali the outcrop of the latter also climbs the hill leaving the Slate series exposed beneath it. It is to be noticed that there is no trace of the Infra-Trias between the slates and the Trias at this place nor anywhere to the north round this end of the hill-mass. On the testimony of Mr. Edwards also there is no trace of the hæmatite or felsite. This is an instance of the peculiarity noticed, page 110. The disappearance of the Infra-Trias from the section in this part of the hill does not appear to have been noticed by Waagen and Wynne as they carry its colour on their map all the way along in this direction to the end of the hill. The band of the Jura-Cretaceous also which is very marked (see sketch, fig. 8) is misplaced on their map and carried too far to the north. It is represented as occurring 1½ miles north-west of Dhumtour in the neighbourhood of a "ziarat."[1] In reality the shaley rocks seen there are part of the Nummulitic series, whilst the true Jura-Cretaceous band vanishes under the alluvium of the river-bed about due west of Dhumtour. It should be remarked once for all that I merely mention such little corrections as these in order that it may be understood that I have not altered Waagen and Wynne's map in these matters of detail from caprice or from holding a different *opinion* as to how the beds should run, but simply as the result of an intimate acquaintance with every foot of the mountain. Waagen and Wynne expressly state at the end of their Sirban paper "we have not sought to map the boundaries with absolute accuracy as yet;" so that I hope these little corrections will be accepted as offered in no carping spirit. When it is as easy to be accurate as not I think it right to call attention to such changes, though small in themselves, because an extended survey of any tract always brings such to light, without in the least reflecting blame on the earlier workers who had to give

[1] Ziarat = sacred grove.

more time to generalities and less to points of detail than those who follow after them.

Coal-bearing sandstone near Shawali.

In the Shawali section the presence of the sandstone in which the coal of Hewson's mine occurs may be noticed on the hill-side about 200-300 feet above the Jura-Cretaceous band, and between the Grey limestone and the Nummulite-bearing limestone. The same bed also comes down to the alluvium at a point west-north-west of Dhumtour about the second "a" of Nawa.[1] This point is within a few yards of one of the pillars erected by the preliminary survey for the railway to Kashmir, so if that project is ever realised it might be worth while trying the bed for coal.

Section north-west of Dhumtour.

All the little ridges with steep ravines between them lying betwen Dhumtour and Shakur Bandee in the neighbourhood of Ookhreeluh are composed of Nummulitic limestone and shales. The latter are principally confined to the more central part of the area corresponding to the centre of the general synclinal into which the rocks are here thrown. The hill-sides are very rough (except where the shales give a pleasant foothold) and so strewn with weathered blocks across which it is difficult to pick one's way that the real structure of the subsidiary folds borne on the general inverted synclinal is difficult to make out.

Unconformability of the Jurassics on the top of the Trias.

Returning to the south-western end of the hill mass we may note the remarks of Waagen and Wynne[2] that "the unconformability of the shales (Jurassic) upon the older rocks is most easily to be observed on the long spur south by west from the summit of Sirban, the surface of the underlying triassic limestone being eroded, pierced by holes of boring molluscs and successively overlapped by the Spiti shales." All this I can corroborate. The same appearance is

[1] These and similar expressions will be understood to be elliptical — the full expression of course being "the place on the hill corresponding to the 'a' of Nawa on the map."

[2] Sirban Memoir.

also noticeable near Shawali. This successive overlapping of the shales above the Trias is particularly evidenced in places where a deposit of martite forming the bottom layer of the Spiti shales, and only an inch or two thick, covers the outcropping faces of the Trias, like a stair-carpet. The holes made by the boring molluscs in the same way may be found on both horizontal and vertical surfaces of the rock below.

The nature of the unconformity is very similar to that between the Productus shales and the Carboniferous quartzite of the Central Himalaya of Kumaun. All the same appearances in the field are generated.

General remarks.

We have now gone over the structural details of the Sirban hill in as concise a way as the nature of the subject allowed. I have not thought it worth while recording the varying amounts of dip observable at different places, because in a steep rocky hill of this kind with towering precipices and deeply cut-back ravines, so much of the solid geology is seen that a surface dip record would be a feeble and misleading account of the huge folds whose limbs have different inclinations at different depths. If the horizontal section No. I which traverses the most typical part of the mountain be studied in connection with the map and the two geologically-coloured views of it, there should be little difficulty in grasping its main geotectonic features. A few general remarks may, however, be made here. The prevailing direction of strike is north-east and south-west, a law seldom departed from. The prevailing direction of dip is north-west, normal or inverted. But rarely is there a dip to the south-east. No doubt dips to the south-east were once present, but nearly all such have become inverted in the process of the gradual growth and development of a set of folded flexures out of a previously gently undulating condition of the rocks. In some cases the inverted limb continues, and in others a reversed fold-fault represents it partly or wholly. Three most striking fold-faults of this kind have come about in the Sirban area. The first and perhaps the largest is a matter of inference and follows the north-west edge of the mountain,

separating the slates to the north from the younger historical rocks of Sirban. Owing to the recent gravels which occupy the valleys to the north of Sirban this fault cannot be actually seen, nor can it be represented on the map, because its actual position cannot be fixed. The evidence for the important nature of the fault is of course furnished by the steady dip down of the Infra-Trias in the direction of the slates as if it would pass under them, a condition which would be unintelligible without a fault of no small dimensions coming between them. An accurate estimate of its throw is impossible, but 4,000 feet would probably be under the mark, provided, as seems likely, that the fracture was complete and had entirely replaced the middle limb of the generating sigmaflexure.

The second fold-fault has been already referred to as the north Sirban fault. It marks a second line of intense folding or tearing and faulting of the rocks. Its throw varies at different points, but must reach 2,000 feet near the centre of the mountain-mass.

The third important fold-fault cutting through the hill east of Tanakki, and the two or three subsidiary faults in the neighbourhood, are all of the same nature, and in many places furnish clear proof of their origin in a sigmaflexure, by remnants of the middle limb of the latter being still left in full view on the steep side of the Bazdar glen (see Horizontal Section No. I).

From the evidence before us, therefore, laid bare in the slopes and precipices of Sirban by the chisel of time, it becomes very clear that this part of the Slate zone has been the seat of immense disturbance of the strata since the latter were deposited horizontally on their varied sea-bottoms. The three unconformities indicated, one at the base of the Infra-Trias, one at the base of the Trias, and the third at the base of the Spiti shales, also inform us that the disturbance of the area has gone on from primitive geological times; and that though the present folds and lines which dominate the earth's crust at this point must date from post-Nummulitic times, they are perhaps only the last phase of a continuing upheaval (with

folding) of the area since the deposition of the great and ancient Slate series.

Sections in the Slate zone north-west of Abbottabad.

The country to the north-west of Abbottabad, which is comprised within the Slate zone, is simply a continuation of the monotonous slate hills which form the wonderfully regular chain on the south-east side of the Miankhaki stream. The slates are unbroken by anything but a few harder beds of quartzite here and there, and by one or two very insignificant trap dykes. There are no limestone bands to mark out the nature and amount of the flexures into which the rocks are thrown.

At one point below Khotukka village, over against the Trias of Sulhud, there is an isolated block of Trias limestone standing alone on the slates. It is probably a detached piece not in its normal position. It is one of the masses called "erratic" by Wynne, but there seems little reason for regarding its position there as due to glacial action or any method of transport other than a displacement due to earth movements, or probably to a mere landslip of very ancient date.

As regards the relation of the north-western side of the Slate zone here to the schistose and metamorphic zone, it will be better to postpone any remarks until the latter zone comes to be described in detail.

Slate zone: Sections near Meerpoor, Kakool, Turnawaee, Dubbun, and Gurhee-Hubeebooluh.

Between Sirban mountain and the complicated area now to be described there is a wide stretch of alluvium forming what is known as the Abbottabad dharah, or plain: beneath which all the rocks of Sirban vanish to reappear again in the neighbourhood of Meerpoor, Kakool, and Mundroch. In elevation this plain is about 4,000 feet, and it is deeply cut into by steep-sided little "nullahs," *e.g.*, the Jub N., most of which carry their water to the Dore river. On the north side of this

Abbottabad plain.

plain, where it is merging into the Mansehruh plain, the drainage goes the other way and eventually joins with the Sirun river. Here the nullahs are even more deeply cut down than on the southern part of the plain, and they wind about between walls of clay and gravel, 200 or 300 feet high, in the same confusing way that they do in the country south-east of Hureepoor. The cause of their deep channel seems to be the same here as in the latter place, namely, the bare nature of the slate hills in the vicinity, which are almost destitute of all vegetation whatever. The rain in no case is held back for a time, but immediately after a shower rushes madly down-hill, and collecting into a fierce torrent scours out a passage for itself by cutting vertically through the soft alluvium. On this account the Sirun river, like the Dore, is subject to sudden spates, and the crossing of it at Khakee and Sher Ali Shah is often as uncomfortable a proceeding as of the latter at Sultanpoor. Similar rushes of water caused by the melting of the winter snow on the hills all tend to keep these nullahs of the steep-sided nature that I have described. Much more water comes from afar in the hills than from the near vicinity, for the reason that much more rain falls on the hills than in the neighbourhood of Abbottabad; hence, in a measure and on a small scale, these little deep-sided ravines are similar to the large cañons so characteristic of rainless areas. Still here, as in the Hureepoor plain, there must have been a time during which the alluvium of this plain was being formed instead of being cut away, for the plain and its deep channels are not such as could be produced by streams alternately eroding and depositing.

It would seem as if this change in the nature of the action of the streams might have been brought about by a general elevation of the country within recent times, which, having steepened the river and stream gradients, would have caused denudation to go on where before was deposition, and deposition to be relegated to a lower level. But there is also a possible cause in the demolition of the forest which, no doubt, went on over all these tracts of what is now bare hill-side in the earlier periods of man's occupation of it.

There seems to be no reason for the idea that this plain was once a lake basin, because, as I have already explained, the altitude of the surface of the alluvium varies within large limits, and there is a gradual change of level (without any sudden drop) from 4 000 feet at Abbottabad to 1,100 at Turbeluh.

Generalities.

The portion of the Slate zone, in which one or two typical sections will now be taken for description, comprises the strip of country south-east of the great Crystalline and metamorphic zone, extending from Meerpoor to Gurhee-Hubeebooluh and with a width of from two to four miles. It is chiefly remarkable for the narrow width of the outcrops of sharply-folded repetitions of Infra-Trias and Trias. Rocks younger than the Trias are scarcely visible in this little bit of country, but they come in strongly to the south-east of it on the Abbottabad side of the Tandiáni ridge. It is apparent, therefore, that this area, which for convenience is placed with the Slate zone, might with equal propriety be represented as a sub-zone of Trias and Infra-Trias rocks among the Slate zone. I have already remarked that the four great disturbance zones into which I have divided the district may sometimes be again divided into smaller subdivisions, and the present is an instance in point. The north slopes of Sirban hill, in like manner, might also be placed in a sub-zone, which is the precise equivalent of this.

It is a difficult and out-of-the-way bit of country to penetrate into. The great complex of folds and faults are all striking N.E.—S.W. or N.N E.—S.S.W. Beyond Meerpoor the Slate series is not in evidence until the Koonhar river is reached. The boundary line between the Slate zone and the Crystalline and metamorphic zone is a sharply-faulted one.

Section near Meerpoor and Kakool.

About one mile N.N.W. of Meerpoor village and a short distance to the east of the Abbottabad-Mansehruh road we find a section which is the counterpart of the one at Koti-ki-Khubbur (Sirban sections). Beneath high scarped cliffs of the Infra-Trias limestone presenting

bold precipices to the west there occur the lower members of the Infra-Trias, namely, purple quartzites and sandstones followed in descending order by purple shales, and then by traces here and there of the conglomerate which unconformably overlies the Slate series. The unconformability of the one above the other, and the actual sequence, is not so well seen as at the south-west end of the Sirban Hill range, but with a little care the mutual relations of the individual beds can be made out. The outcrop of the slates can be traced for a little over a mile along the base of the hill face, after which they sink beneath the alluvium, and the latter hides everything up to the Infra-Trias limestone.

The whole of the great semi-isolated hill-mass, of which these cliffs are the western side, lying between Meerpoor and Bandee Peer Khan is composed of Infra-Trias limestone; its elevated, rugged, and barren crest shewing gently undulating folds in the strata with a N.E.—S.W. strike. At the very northernmost end of the hill, where the spurs descend to the level of the alluvium, the road to Mansehruh takes a sudden turn to the north-east and goes for half a mile parallel to a number of marked strike ridges in the limestone.

South-east of Meerpoor in the direction of Kakool the bare hill-sides and marked bedding of the Infra-Trias limestone are seen to perfection in profile from the Abbottabad-Mansehruh road. At Kakool the hill-sides recede somewhat, and it is necessary to ascend a gentle slope of alluvium inbaying among the hills before we can begin to trace out the very complicated cross-section at this end of the geological complex. The village of Kakool tops the alluvial slope, and behind it a great number of straight spurs and gorges descend from the direction of Koond (7,841 feet), their general lie coinciding with a number of closely-packed isoclinal folds of rocks embracing representatives of the Infra-Trias limestone, the felsitic rock and hæmatite, and the Trias limestone. The left-hand end of horizontal section No. 2 had better be consulted here for details, as words are inadequate to do justice to the complications. East and south of Kakool the sharply-carved edges of the rocky spurs display

a thicker band of Trias limestone outcropping down the ridge from Maira and Buloliya and enfolding in a steep synclinal reversed to the north-west a patch of the Spiti shales, which are traceable from the hill behind Kakool as far as 1 mile north-east of Buloliya. The Trias then turns over in an arch, the south-eastern limb becoming sharply cut off by a fault which brings in the Infra-Trias again. The last band may be followed all round the edge of the hills in a south-westerly direction to near Nawashahir (3,954 feet) where a straight and steady fault brings in the great Nummulitic formation. The Infra-Trias along this line is spread out in a flat platform, receiving above it Trias limestone in a very gentle synclinal fold. Such is a brief account of the rock bands as projected on the rim of the alluvial bay from Meerpoor to Mundroch Chhothee.

The following more noteworthy points in the section may here be given. As regards the Infra-Trias last mentioned near Mundroch, it consists of purple shales in a rather obscure outcrop next the fault, covered by purple sandstone, and a white, powdery felspathic sandstone. In all ways these rocks resemble the sandstones and shales which we found representing the Infra-Trias near Shakur, Bandee, and Bazdar. No conglomerate is exposed at this point, nor are there any calcareous members of the Infra-Trias present. Dipping at a low angle north-west at first they then flatten out as mentioned above. Just about the "C" of Chhothee, and the "n" of Mundroch Buree fragments of hard hæmatite and brecciated felsite were found, but the rock could not be traced to a position *in situ* between the Infra-Trias and Trias. Such places as were explored, as for instance the edge of the hills south-west of Kakool shewed the latter superposed on the former, without any intervening volcanic rock. Nevertheless, the fragments strewn over the exposed surface of the lower series plainly indicate that it does exist in certain places, though not in all.

North of the village of Kakool the stream-bed is strewn with large fragments of felsite in considerable quantity—a fact accounted

for by the numerous beds of it which appear in the intensely folded ridges of this part, and also by the thickness of the bed lying on the north-west face of the ridge north of Kakool, which is from 30—40 feet thick.

All the individual beds here referred to may be traced up the steep hill spurs and ravines towards Koond.

About 2 miles north-north-east of Kakool, about the junction of the felsite and the Trias limestone, Hira Lal found a steatitic shale or clay.

Half a mile east of Kakool we have the following section ascending towards the south-south-east. After the synclinal in the Trias and Jurassics behind Kakool we pass over a fault, and Infra-Trias limestone sets in. This apparently becomes interbedded with and passes up into a great thickness of purple and pale shales and sandy beds. Above this comes the felspathic sandstone and then the Trias limestone. The points of peculiarity in this section are the apparent passage upwards of the Infra-Trias limestone into shales, and the absence of any felsite in the section. At what point the base of the Trias begins is uncertain, but most probably it is at the base of the felspathic sandstone.

Turnawaee sections.

Turnawaee village is situated just on the north-west side of the great boundary fault which, along this line of country, divides the Crystalline and metamorphic zone from the Slate zone. Its immediate foundations are a gravel plateau resting in the valley of the Icher N. with steep and high cliffs cut through by that stream.

The distinction between the two sets of rocks on each side of the boundary fault is a very marked one at this place, as it is all the way on from here to Gurhee-Hubeebooluh. On the one hand the schistose rocks extend from the fault in gently undulating spurs, and expose along the stream-beds a uniform low cliff of white and shining micaceous débris, which incessantly powders down from the crushed or, as one might almost say, churned-up schists which compose it. On the other hand the sombre-coloured limestones and

associated rocks rise into bold thickly-bedded rock-masses as they proceed by jagged vertically-stratified spurs to join up with the Sichar peak (8,654 feet). The Icher N. drains between these spurs from Sichar peak and receives branches from the direction of Koond and other prominent ridges. Its gorge is very steep and shut-in in places, and its final gathering slopes under Sichar present 3,000 feet of steep untrodden precipice.

The section exposed up this gorge is, in all essentials, a duplicate of that in the neighbourhood of Kakool. The first rock met with east of Turnawaee after the great fault is passed is Trias limestone striking a trifle east of north. Next comes Infra-Trias limestone for a considerable distance, and that is followed by thin bands of felsite, Trias, etc., as seen in the annexed section, fig. 9.

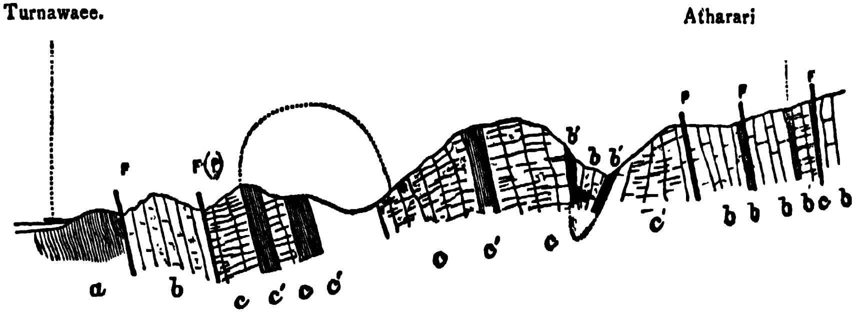


Fig. 9.

b = Trias limestone.
b' = Felsitic and hæmatitic rock.
c = Infra-Trias limestone.
c' = Yellow shales in *c*.
a = Schistose series.

The reader will find little difficulty in joining up the Kakool and Turnawaee sections. The almost vertical lie of the rocks makes the strike and outcrop almost coincident, and the narrow bands travel in a perfectly straight course from point to point.

But the difficulty of understanding rocks packed together in this marvellous way in thin strips divided up by numerous faults is so great that a reconstruction of the folds originally taken by the rocks

is nearly impossible. We shall, however, be safe in concluding that the horizontal compression which the rocks have sustained here is even more intense than that which the Sirban area sustained.

Section near Dubbun.

The Trias band which lies next to the schists in the last section is continued across the hill spurs to near Hazira, when it skirts the south-east side of the Icher (another stream of the same name as at Turnawaee), leaving the schists occupying the other side. Thus the great boundary fault here coincides with the flat and open stream-bed, which is the common high-way between the lower country of the Mansehruh plain and the high level valley of Dubbun. The long straight reach along which the fault passes is monotonous and bare, save for a few elder groves at intervals in the shingly bed. After a little over a mile the fault leaves the stream-bed and passes along the north-west side of valley for some way, eventually returning to the middle of the high valley of Dubbun. Between the latter and the lower reaches lies a steep and weary climb up the narrowed gorge in the Trias limestone band east of the fault. This band continues diagonally across the Dubbun valley and occupies the steep western slopes of Phoot hill (6,654 ft.), whilst the boundary fault is indicated by a marked gap or pass at the head of the Dubbun glen where the Icher drainage is parted from the Rutwala drainage.

The country between Sichar and Phoot trigonometrical points was difficult of access at the time of our visit; the sky was threatening snow, and had we lingered among these high valleys we might have been weather-bound for a month or more. Consequently the actual details of the continuation of the bands of the Infra-Trias and Trias from the Turnawaee glen in this direction, and their dying out or confluence, as the case may be, was not followed out by us. Hira Lal, however, crossed from Turnawaee to Dubbun *viâ* Lagal bun and was able to mark out two separate folds of Trias limestone, felsite and Infra-Trias, whilst Edwards followed an apparently very thick outcrop of the felsite along the ridge near Phoot, and subsequently the cliffs at the head of the Booee stream under Phoot were shewn

by the latter to be of Infra-Trias limestone. I myself was at the time more or less incapacitated for hard scrambling by an accident to my right wrist.

Still, apart from details, it seems clear that we have all along this bit of country, from the Turnawaee glen to Dubbun, a strike continuation of the complex of steep isoclinal folds of Infra-Trias and Trias, such as were found in the Turnawaee gorge and south-west of Koond in the direction of Kakool and Meerpoor.

Section down from the Rutwala stream.

At the little pass north of Dubbun, we are on the watershed dividing the streams going south-west to the Indus from those going north-east to the Koonhar. Functionally, therefore, it is a continuation of the north and south watershed which goes by Tandiáni Mianjani, etc., referred to (orography of the Slate zone, p. 95) and the gap is homologous to Beerun Gullee, Nathia Gullee, etc., to which reference will be made later. The true *analogues* of the gap are of course to be found along the line of the boundary fault, where a marked elevation of the hill spurs to the south-east and a lowering of them to the north-west, together indicate that line very plainly.

The way up to the pass, along which we have come, has been a gradual slope leading by the Icher N. from the level of the Mansehruh plain; but the descent to the Koonhar is of the nature of a sudden drop. The Mansehruh plain to the north near Phughu, where the road to Gurhee-Hubeeboolah goes, gives way in a similarly sudden way, the earth seeming to open at our feet in deep ravines and gorges tributary to the Koonhar. The view from the little pass into the basin of the Koonhar is very striking. Across the valley an endless prospect of ridge and gorge, arranged one behind the other, lead up in the far distance to the Nanga Parbat group of snowy peaks in Kashmir, and according to the season are either clothed in limpid sunlight and purple of the deepest hue, or grey and storm-strewn, as mist and cloud in advancing hosts drop fatness among the valleys and dredge white with snow the bare summits and higher crests.

The geological section exposed in the Rutwala stream is very simple as far as Sihali, being entirely among the schistose rocks. At Sihali the boundary fault crosses the stream at the same place as the latter takes a turn to the east. The rocks east of the boundary fault are nothing but a much-folded complex in the Infra-Trias limestone with no representatives of the Trias or felsite left.

The following section will illustrate this point :—

Sihali. Koonhar R.

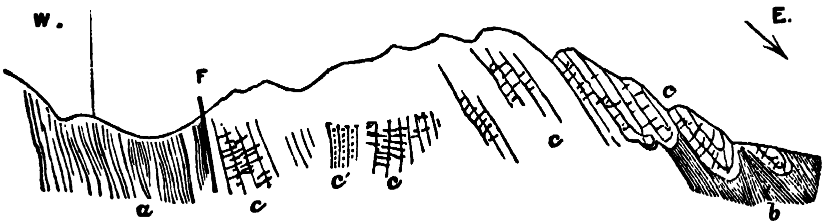


Fig. 10.
c' = White quartzite.
c = Infra-Trias limestone.
b = Slate series.
a = Schistose rocks.

Section near Gurhee-Hubeeboolah.

The whole of the hill-side on the right bank of the Koonhar between the Rutwala stream and Gurhee-Hubeebooluh is composed of a continuation of the Infra-Trias limestone of the above section, presenting sheer precipices to the river, with the exception of the actual river-bed itself, which, in several places, is seen to be cut down to the slates beneath. The junction of the two rocks is not well seen, and there seems to be no trace of the basal conglomerate, though some beds of the purple quartzite or sandstone, visible along the river-bed, may belong to the Infra-Trias. There are indications that the Infra-Trias limestone is much folded in its relation to the slates.

On the left bank of the Koonhar, round about Gurhee Hubeebooluh, there occur slates, schistose slates, and schists. In the space between the Rutwala stream and Jubree the change from slates to schists has been accomplished, and from the occurrence of all intermediate steps between a normal slate and a normal schist, it seems

to be established that there is a real passage and not an apparent one only between the two. Down-stream from this locality nothing but slates persist, and up-stream nothing but schists. On the left bank of the river, therefore, there is no evidence for a continuation of the boundary fault between the Slate zone and the Crystalline and metamorphic zone which we have hitherto seen to be persistent.

The bed of the Koonhar at this locality is in a wide open valley inclining to the U shape rather than to the steep V shape which we shall see it possesses further down its course. That this is an indication of the work done by glaciers in post-Tertiary times seems to be likely from the evidence I shall presently notice on the high hill-spurs. The present river-bed is filled with recent gravels in terraces rising to 300 ft. above the river. They present no peculiarities different from similar deposits in the Dore and other drainage lines in Hazara.

Section along the ridge south of Laichi Khun and the vicinity.

The portion of the ridge, south of the pass going between Gurhee-Hubeebooluh and Muzuffurabad, and which lies in Hazara, as also the continuation of the same ridge down to the point where the Jhelum and Koonhar join one another, is composed of slates or schistose slates.

Along the line of the road from Gurhee-Hubeebooluh up to the pass the slates are faintly schistose only. In the lower parts of the hill slopes the strike is north-north-east to south-south-west, but higher up it becomes north and south.

Northwards from the pass up towards Srikote and Laichi Khun and quite close to the pass, we come first upon some of the confused heaps of rocks of several formations, which, I am of opinion, are of glacial origin. Along with them there is a large amount of powdered-up purple and sandy material together with Nummulitic limestone, which mark the north-west end of a strip of the Murree series, which we may see outcropping in a south-east direction towards Domel in Kashmir. Round about Tangar these beds are seen to better perfection. Although the section is disfigured to a great extent by débris and old morainic material, we can nevertheless distinguish a good band of Nummulitic limestone striking north-west to

south-east along the north-east side of the outcrop of Murree beds and there is also a trace of it on the south-west side of this band, facts which indicate a regular synclinal in these strata modified by faulting and crushing.

Before going further I may draw attention to an important structural feature. We have now arrived just on the borderland, where the normal strike of Hazara, *i.e.*, north-east and south-west (approximately), gives way to that of Kashmir, which is generally speaking north-west and south-east. The former indicates that it belongs to the great Hindu-Kush system of earth-movements, and the latter that it belongs to that of the Himalaya. If Mr. Lydekker's map of Kashmir be consulted in conjunction with mine of Hazara, it will be seen that the above statement is in accordance with facts. Without dwelling any longer just now on this point I may note a curious feature of the Murree beds which compose this thin band in the neighbourhood of the pass. Whilst the general outcrop of the band runs north-west and south-east, which should indicate a strike much in the same direction (considering the high dips usually found in these parts and the evident synclinal into which the rocks are thrown), and whilst the Nummulitic limestone bands on either side of the Murree series also trend in the same direction, it is nevertheless a curious fact that the only individual dips found in these Murree beds are in an exactly contrary direction. Near Tangar, in fact, there is a fine cliff exposure of the Murree sandstone dipping due south-east at 60°. I do not wish to lay too much stress on a single observation of this kind in a rather obscure section; but if it has any meaning at all it would seem to be connected with the great structural feature mentioned above, namely, the line of change between the Hindu-Kush and Himalayan systems of earth-movements. The thinness of the band of Nummulitic limestone to the north-east of this Murree series, and the appearance of the slates next to the band on its south-west side, plainly indicate fold-faults running north-west—south-east. It should be mentioned that the slates in close proximity to the Murree beds have their foliation strike rapidly but gradually changed from

a north-east—south-west to a north and south, and then to a north-west—south-east strike; so that at the fault between them and the Murree beds their foliation strike is parallel to the outcrop of the Murree beds. The above faults are further indicated by the very much broken up and powdered condition of the next rock to the north, namely, the Infra-Trias limestone which rises in bold scarps.

As we continue up the ridge towards Srikote over this limestone, we find the beds settle down to a north-east—south-west strike, with a north-west dip of 40° to 60°. At the first rise in the ridge, however, there seems to be a small inverted anticlinal, exposing some dark-coloured slates entirely unmetamorphosed. After passing these there is a steady ascending series in the Infra-Trias, as far as the first high point at the south end of the Srikote ridge. The Infra-Trias limestone here is a little abnormal in character. It is somewhat thinner bedded than that of Sirban hill which I take as a type. It is full of cherty bands more or less brecciated in places. Near the high point just referred to, and as we reach the upper horizon of these rocks, the cherty bands increase in number and size, and they become more siliceous and more definitely banded and brecciated as the top is reached. A tumbled mass of very rough crags then shew a clastic breccia or agglomerate of this rock, with a few well-rolled pebbles of white quartzite, and with a sandy and calcareous matrix not very prominent. This clastic breccia and pebbly layer seem to indicate an uncomformity, for the next rock above is a coarse slightly calcareous sandstone which seems to pass down into the conglomerate. The sandstone is variegated in its colours and is not unlike the coal-bearing sandstone of the Dore river. It is about 30 feet thick, and it gradually passes upwards into dark concretionary Nummulitic limestone of the ordinary Hazara type, with minute foraminifera running in strings and throngs among and between the concretions. In this section, which shews no signs of faulting above the Infra-Trias, there is neither Trias, Jura, nor Cretaceous represented, and there is also absent the limestone, which, for convenience, I have placed (not without misgivings) with the Nummulitics, namely, the so-called Grey

limestone. The absence of the above formations, coupled with the conglomeratic character of the base of the sandstones, and the inclusion among it of an angular clastic breccia so plainly re-made from the *in situ* brecciated cherty bands of the Infra-Trias, argue an unconformity at this point.

The rest of the way along the ridge up to Srikote, now fairly horizontal though rugged, is composed of Nummulitic limestone. The dip has slackened off from 40° to 60° north-west and is now slightly undulating only.

Srikote point itself is just situated on the axis of a sharp anticlinal curve in the Nummulitic limestone. Its northern slope is a dip plane of 70° north-west in a good exposure, after which comes a fault and the section repeats itself, beginning with the Infra-Trias limestone, of which there is only a small amount exposed, then the sandstone with the angular agglomerate at the base, and then Nummulitic limestone again for nearly a mile, the ridge becoming very rugged and broken. The strike gradually changes to east and west and the dip to the north. Pale limestone is now interbedded with purple shales, and then follow several hundred feet of purple shale, and then the latter interbedded with Murree sandstone. The Murree sandstone then increases in quantity, and it and the shales continue the rest of the way to the top of Laichi Khun peak (8,811 feet).

The outcrops of these beds to the west down the slopes and likewise to the east were very well seen in their relative positions from the ridge.

The position of the Murree beds, capping as they do a great hill such as Laichi Khun, and lying in such evident gentle superposition on the top of the Nummulitic limestone as a great outlier, is a noticeable feature here, for, as we shall see when we come to the description of the Nummulitic zone and the north Tertiary zone, this clear and straightforward superposition of the one on top of the other is but seldom found towards the plain-ward edge of Hazara.

The Infra-Trias and Nummulitic limestones described in the above section are clubbed together both on Lydekker's map of Kashmir

and Wynne's unfinished map of Hazara; but whilst the former marks them as altogether Nummulitic, the latter marks them as Infra-Trias. Both have represented a partial truth, but not the whole truth. As regards Wynne, I can only conclude that he never ascended to the top of this ridge, probably for want of time, for the Nummulitics are every bit as characteristically developed there as anywhere in Hazara.

From Srikote to Laichi Khun the ridge is sparsely covered with forest of Deodar, Biar, and Paludar. A little beyond the peak of Srikote there is a flat little valley with a spring of water and a few cultivated fields and huts which were deserted at the time of my visit. Otherwise the ridge is uninhabited. A magnificent view is obtained of the head-waters of the Kishenganga river and of the snowy peaks capping the range which gradually ascends from Laichi Khun and bends round in a fine arc towards the north-east and east-north-east. It should be noticed that in continuing our section up to Laichi Khun across the Tertiaries we have really crossed over the boundary between the Slate zone and the younger zones. This was done advisedly so as to complete the description of a natural section.

Old moraines.

The steep spur of Infra-Trias limestone, over which we began to ascend on the way up the Srikote ridge, is cut into by deep little water-courses with steep shut-in sides towards the south-west in the direction of Gurhee-Hubeebooluh. A rather difficult and tedious pathway goes from the pass on the ridge towards Gool Maira in a north-west direction and follows the base of the Infra-Trias limestone, along what is a continuation of the fault between it and the band of Murree beds going to Tangar. The exposures here shew much crushed and powdered Infra-Trias limestone and whitish quartzite at the base of the Infra-Trias cliffs. Below this, all the descending spurs are composed of slate in their lower parts, and are covered up as to their upper parts by an irregular accumulation of blocks, chiefly of Infra-Trias limestone, although there are also some few of quartzite and Nummulitic limestone. These continue to the south-west spur of Srikote overlooking Gool Maira, and then spread out and cover the top of a minor spur east of the 5,908 feet spur. The sides

of the spur everywhere give exposures of the schistose slates, but the top capping is a coarse agglomeration, sometimes consolidated and sometimes loose, sometimes made up of Infra-Trias blocks, sometimes of Nummulitic limestone blocks, and sometimes of Murree sandstones also in blocks. Occasionally the three rocks in this fragmentary state are intermingled. The whole of this accumulation is manifestly a surface deposit, and I am fairly persuaded that it owes its origin to the action of glaciers, which in the last glacial epoch must have descended from Laichi Khun and Srikote or from some of the higher ridges up the Khagan valley. A similar deposit on the spur due east of Gurhee-Hubeebooluh, chiefly composed of Murree sandstone, appeared at first so homogeneous that I was inclined to regard it as an outlier of the latter. Afterwards sub-angular and rounded pieces of Infra-Trias and Nummulitic limestone convinced me that it was not *in situ*, but evidently of the nature of a rubbish heap of sub-angular boulders. This *débâcle* is very thin, not more than 30—50 feet thick. It nevertheless lies for the considerable distance of half a mile at different elevations along the spur, following the crest of it as it winds to lower levels. There is no continuation of the deposit along the spurs to the east.

Other than as a glacial moraine the only ways in which we could account for this deposit are—

(1) As a bed *in situ*, but much broken up.

(2) As scree-material.

The first of these seems to be untenable as a hypothesis, by the facts stated above that there is no general strike of the aggregated fragments. They continue neither along the crests of the spurs to the south-east or north-west, nor do they strike down into the streams between and on each side of the spurs, as they would if they were part of a faulted or in-folded mass.

The second at first sight seems not improbable as an explanation. It looks reasonable as a hypothesis that these rubbish heaps of angular material might be merely fallen débris from the hills above. This explanation had, however, to be discarded in favour of glacier transport on account of the more or less sorted way in which the beds occur:

heaps of one rock alternating with heaps of another, and only sometimes mixed; and secondly, because of the absence of slate fragments in the accumulation on the top of the spur east of Gurhee-Hubeebooluh, notwithstanding that the main ridge south of the pass directly above the deposit is entirely composed of slates; whereas, on the other hand, nothing is so well known as that glaciers creeping along under cliffs of particular rocks will be loaded here with one sort of débris and there with another, and that when they come to melt at lower altitudes they will leave a roughly sorted accumulation of particular rock-fragments far away from the solid bed from which they were derived. Lastly, these rubbish heaps, so high (3,000 feet) above the present drainage, and fixed on the tops of hill spurs are (with the exception of those immediately north-west of the pass) quite out of the present line of drainage, along the sides and bottom of which scree-material would tend to accumulate.

Absence of metamorphism in the Tertiaries.

I must now invite attention to one of the most important deductions that may be drawn from the Gurhee-Hubeebooluh sections. In a previous memoir (Physical Geology of the Sub-Himalaya of Kumaun and Garhwal[1]) I remarked on the absence of metamorphism in the Upper Tertiaries and Nummulitics in the vicinity of the schistose and granite area of Kalogarhi (also called Kalandanda, and latterly Lansdowne) as offering a not very rigid proof that the Tertiaries at least were deposited later than the date of the general metamorphism of the Himalaya by the intrusion of the gneissose-granite.

We have here before us in this corner of the mountains a much more satisfactory proof, inasmuch as the Murree beds, the Nummulitic limestone, together with the sandstone beds at the base, lie all in direct and normal superposition immediately above thin-bedded rocks exhibiting distinct metamorphism. They form outliers capping the tops of the hills, whilst the schistose slates form the base of the same hill range.

And yet the soft sandstones, the purple shales and the nodular

[1] Mem. Geo. Sur. Ind., Vol. XXIV, pt. 2.

limestones differ in no possible way, not even in hardness or coherency, from their contemporaries along the southern border of Hazara.

Sections near Nuwanshuhr, north of the Dore river, across Bunyan Hill and Gulee, up the Hertoh river, and in the neighbourhood of Tandiáni.

General remarks.

To the south-east of the last-described bands of rocks, which may be considered collectively as a sub-zone of Trias and Infra-Trias among the Slate zone, there comes a large area of hilly country, characterised by the upper members of the stratigraphical sequence (Jura, Cretaceous, and Nummulitic), and which is as manifestly a strike continuation of the north-eastern portion of the Sirban massif, as the foregoing area is a strike continuation of the north-western portion of the same. Instead of the wide Abbottabad plain lying between the two areas, as in the latter case, there is only the constricted valley of the Jub, occupied by recent gravels and clays, through which the tiny but rapid stream of that name scours its way. The three great hill-spurs, given off from the Sirban mass between Kot Nawa, and Shakur Bandee, composed of the rugged Nummulitic limestone, have very palpably a structural continuation with the similar spurs on the north-eastern side of the Jub, which run in parallel directions away towards the north-east.

Viewed from the south-west these hill-spurs, and Bunyan hill rising behind them, present a very bare appearance. There is no forest, scarcely any scrub-jungle, and only very seldom are there sufficient soil-covered patches of ground on which a village can thrive. But behind Bunyan Hill the heights of Tandiáni, averaging 8,000 feet, and the surrounding slopes are richly wooded with a temperate flora.

Section from Nuwanshuhr to Dhumtour.

The section now to be described adjoins the one from Meerpoor to Mundroch *viâ* Kakool, described p. 121. The point at which we left off the description of the latter was at the line of great fault

between the Nummulitics and the Infra-Trias (see also horizontal section No. 2). That this fault is of considerable importance and one of the largest yet brought under our notice is evident from the way the Nummulitics come in contact with some of the lowest beds of the Infra-Trias. Nevertheless, along the same line of strike in the Sirban sections this fault was non-existent. It was replaced by an ordinary fold of the rocks, with a regular ascending series up to the Nummulitics in the valley going north-east to Shakur Bandee,—see sketch section, p. 112. If we now wind our way along the foot of the hill-spurs from Nuwanshuhr to Dhumtour, we shall find for a very considerable way that we cross nothing but the outcropping edges of the Nummulitic formation. In themselves, these beds of nodular limestone, shale, and marl, often crowded with foraminifera and shells, are somewhat confusing. It is difficult to correctly estimate whether the section is a uniformly descending one in the direction of Dhumtour, as the general lie of the rocks would indicate, or whether there are one or more folds with inversions to reckon with. The section (horizontal section No. 2) of this part represents the results of several traverses in and out of the deep straight little gorges near Nuwanshuhr and across the stony slopes and hollows north-west of Gulee. It will be gathered from that section that at the little pass near Gulee, where the present road to Tandiáni goes, there is a conspicuous change in the general appearance of the section, but it is not certain that this implies any great structural change. Between that point and the fault separating the Nummulitics from the Infra-Trias sub-zone near Mundroch, there are two bands of ochre or chrome coloured limestone containing belemnites in the same state of preservation as are those of the typical Cretaceous band. At the little pass itself there is another band indicated in the section, but cut off by a fault from the surface. It outcrops, however, a little further on in the direction of Tandiáni near Kuthwal. The two former bands are too small to be coloured on the map. From the general nature of the section in the surrounding Nummulitic rocks, as well as from the non-appearance of Spiti shales associated with the Cretaceous, it seems

certain that these outcrops must represent very sharply reflexed anticlinal folds, with very possibly faulting along them. Beyond Gulee in a south-east direction horizontal section No. 2 continues along the line of Bunyan hill and Mohar village, but the sketch-section here given below is a view of the beds as seen along the line of country we are now traversing, namely, towards Dhumtour.

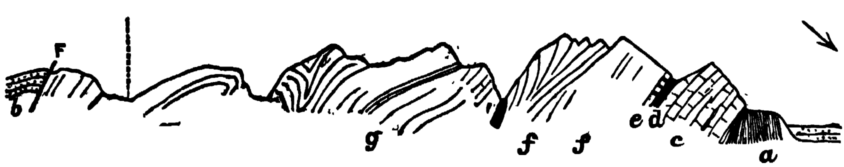


Fig. 11.

g = Nummulite-bearing, generally concretionary, limestone shales and marls.
f = Grey limestone.
e = Cretaceous.
d = Jurassic.
c = Trias.
b = Infra-Trias.
a = Slate series.

From it we may gather that the lie of the Nummulitic formation in this section is by no means a simple one, and that to regard it as a great descending series, whereby a thickness of about a mile would have to be assigned to it, would be a very grave mistake. There are at least two points in the section where very compressed synclinals —with or without faulting is doubtful—must be inserted, as the evidence for them is clearly given by the hill-sides. Any closer working out of the structural features of these exposures would have taken a long time, because the Nummulitic limestone, from its concretionary habit and its want of well-beddedness, tends to obscure itself with talus and surface-deflection.

Not till we approach Dhumtour do we get a decided normal sequence in the series, indicated unmistakeably by the appearance of the coal-bearing bed of Hewson's excavations on the high crest of the ridge, by a good thickness of Grey limestone beneath this, and then

by the Cretaceous and Jurassic formations beneath them; the whole group being in normal order with a dip of 40° N.W. The last two series follow a gap in the ridge, and continue down the stream which divides the final spur of Trias limestone from the rest of the ridge. Finally, beneath the not very thick exposure of Trias in a bold scarped cliff, there appears the Slate series, outcropping at the foot of the cliff and along the edge of the fields in close proximity to the high-road. This normal exposure of the Infra-Nummulitic formations down to the Slates is obviously a direct continuation of the same formations near Shawali in the Sirban sections.

Dhumtour itself is a fairly large village, situated on a flat triangle of gravel and clay terraces, and with a steep descent of 200—300 feet down to the Dore river; these recent accumulations being part of the same continuous valley deposits, which, following the bed of the Dore, ascend gradually by the little stream of the Jub to join up with those of the Abbottabad plain.

Section through Bunyan hill from Gulee to the Hertoh river.

I have already referred to the section north-west of Gulee. To the south-west of that little pass the Nummulitic series of Bunyan hill shews the ordinary grey and ochre coloured shales with nodular limestone, all crowded with foraminifera of rather large size on its north-western slopes, and more massive beds of Nummulitic limestone with a few marked bands of shale on its south-eastern side as it descends in a fine convex slope to Mohar village. The apparent dip on each side of the hill is in towards the hill, but it is more than likely that this does not indicate a synclinal, but is an example of surface deflection on a large scale (see section fig. 13, corresponding to this in the N.N.W.—S.S.E. reach of the Hertoh river). Near Mohar a rough anticlinal, with several breaks or slips of the strata above it to the north-west, brings in several good exposures of the Cretaceous and Spiti shales, the latter being marked as usual by a copious spring of water and a pipal tree, as well as by a flattening out of the hill-spur. Below Mohar the section down to the lower reach of the Hertoh river is an ascending one over the south-eastern limb

of the anticlinal in the Grey and Nummulitic limestones, with a prominent normal fault half-way between. The above anticlinal bringing in the Jura-Cretaceous is a direct continuation of the exposures 1 mile north of Dhumtour in these rocks, but the Trias fails to put in an appearance. On its crest the anticlinal carries a small synclinal.

Sections on the north side of the Dore river between Dhumtour and the Hertoh river.

Between the two places marginally noted the hill-sides to the north of the Dore river offer several very clear sections of the lower Nummulitic and Grey limestones in high scarped cliffs, with the coal-bearing band of Hewson's mine between them, and with the Cretaceous and Jurassic formations below (see sketch section, Rec. G. S. of I., Vol. XXIII, p. 269). All the exposures along this piece of country give evidence of a geological structure, perfectly simple and intelligible when viewed in its broader features; but the minor details, especially towards the base of the hill-slopes and along the (often gravel-hidden) road cuttings north of the Dore, are complicated by small folds, faults, and slipping of the rocks, with regard to which it is difficult to say how much was due to primary earth-movements, and how much may have been subsequently due to gentle yielding of the rocks since the Dore river flowed in its deeply-eroded channel. This question will be further discussed in the final chapter of this book.

The gorge of the Hertoh river.

The gorge of the Hertoh river descends and joins the greater gorge of the Dore river between high steep cliffs, which here and there shew terraces of recent gravel, hardly sticking to the much scored and precipitous hill-sides. Village communication along gorges of this kind varies with the season. During the drier months of the year the boulder-strewn river-bed forms the best and speediest footpath, but when the snow of the Tandiáni ridge is melting, and during the rains which follow, the hill tracks must traverse along the sides of the ravine. They are steep, and, because of the crumbling relics of recent gravel, often afford a very precarious foot-hold; besides, having been neglected during the cold weather, they have generally slipped away in many places.

Those familiar with mountains will be able to form a correct idea of the gorge from this description, and it will also indicate some of the peculiar difficulties of travel in this rugged country. The accelerating influence of gravity down 200 feet of such slopes becomes a practical reality when one sees a mule-load (and perhaps the mule too) of one's kit spinning and bounding to the bottom. The village of Mohar occupies a gentle slope before the final steep descent on the right bank, and Sirbunnuh is perched on a jutting platform of gravel on the left bank with precipitous sides all round, and having a fort-like aspect. Up stream beyond Sirbunnuh, where the Hertoh river takes a direction N.—S. and then N.N.W.—S.S.E., the great convex slopes of the mountain-side steepen to hardly scaleable precipices at the bottom (all such details of contour and slope are lost in the hill-shading of the map, which here and elsewhere gives an imperfect and even wrong idea altogether), in which the great ribs of rock descending from Bunyan hill shew such a steepening of the angles of dip, so gradual but so sure, that one may well be bewildered by the miles of vertically-bedded limestone exposed to view. Here, and in many other gorges of this description to be subsequently described, I have found much food for reflection as to the internal, deep-seated structure of mountain cores; for, however low the angle of dip of the strata along the high ridges, even to as great a depth as 1,000 feet, and however bold the flexures so revealed across the steeply-carved mountain spurs, the impression one gets in the profounder gorges is as if all such dips continuously steepen, and all such flexures vanish by the increasing sharpness of their folding, until they become a vertically-packed set of strata, which seem as though they would continue so indefinitely without resolution.

The lower part of the Hertoh river traverses along the strike of the southern limb of the fold in the Nummulitics, represented by the much broken anticlinal at Mohar. As the river turns gradually to the north, it cuts across the strike more and more, and then two much torn and altered representatives of the Jurassic anticlinals appear, a view of a portion of the more western one being sketched overleaf, fig. 12.

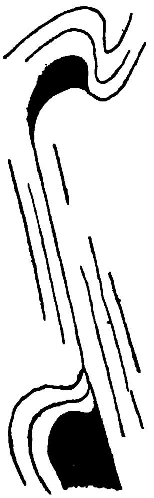


Fig. 12.

The shaded parts represent cores of Spiti shales in the form of completely crushed and churned-up masses of nearly homogeneous carbonaceous clay. From its black and coaly appearance it is one of those beds that might at first sight be mistaken for the coal-bed of Hewson's; but that such is not the case, is proved by the occurrence here and there of undigested fragments. Further away up-stream, about 250—300 feet above the band, the true variegated sandstone or coal-bearing bed appears in a very steep outcrop, from which respectable pieces of anthracitic coal, 100 feet above the river (the aid of a rope is necessary to climb to it), were excavated. The blocks were found, as elsewhere, to be full of bright, shining shear planes, cutting across one another minutely. A sketch section is given below, fig. 13, in which the river-bed and

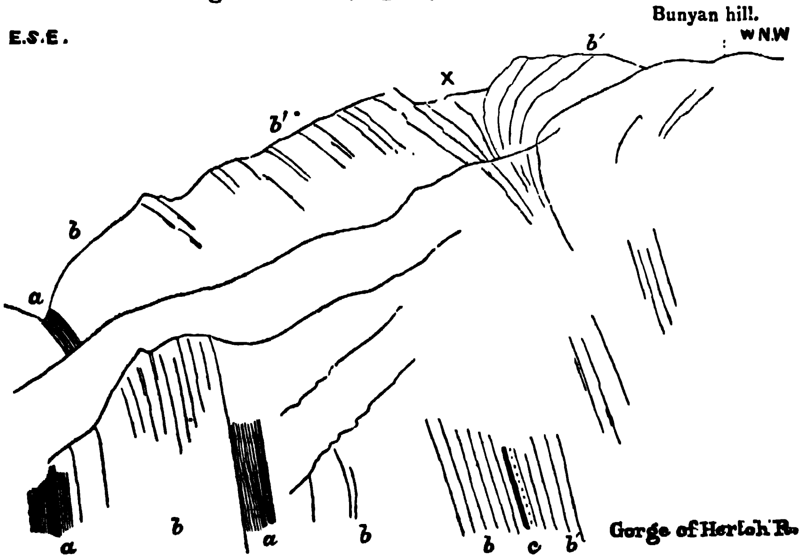


Fig. 13.

b' — Nummulitic limestone.
c — Coal-bed and variegated sandstone. } Nummulitic series.
b — Grey limestone.
a — Spiti shales and Cretaceous.

mountain-slope above are represented together. The variegated sandstone, with smudged and wavy lines of carbonaceous material, in addition to the bed of coal, is shown dipping at 80° W.N.W. along with the neighbouring limestones. The section ascends towards the west-north-west.

On the east side of the second anticlinal there is also another exposure of the coal-bearing bed, not so good apparently as the one to the west. I could not examine it myself, but fragments of coal were brought to me from it. At the point X in the above section there are Nummulitic shales visible on the Bunyan ridge, but none lower down the slope. I conclude that the shales have furnished a line of weakness, along which the strata have yielded and slipped; similar movements having taken place along the line of the Jura-Cretaceous at *a a*. The two broken anticlinals indicated by *a a*, and exposed in the gorge, continue north-north-east up the hill-sides for a long way, their exposures being narrow strips only and following depression on the slopes or the run of a stream-bed. The south-eastern one dies out under Musta peak (8,435 feet), and the north-western one passes across the main ridge to the other side by a small gap and joins up with the prominent band exposed on the north-eastern scarps of the main ridge.

Continuing up the Hertoh river along its right bank by a somewhat precarious foot-path, which runs high above the final abyss, until we reach the point where the gorge turns to the north-east, we cross over a continuous section in the Nummulitic limestone, dipping as before steeply to the north-west or west-north-west until the strike of Gulee is reached, when the faulting and folding begin which introduce the Jura-Cretaceous band (previously referred to as passing by Bandee and Kuthwal. The Cretaceous and the brown sandstones beneath display here a fair proportion of fossils, but want of time prevented me from visting the locality again for the purpose of collecting them.

Following the right bank of the north-east reach of the Hertoh along the road to Tandiáni, but considerably above the bed

of the river which retains its gorge-like aspect, we may trace the Jura-Cretaceous band beyond Kuthwal, when it mounts the hill-side to Kholia and then spreads out, bifurcates, and uncovers a great and fine anticlinal arch of Trias limestone. The western bifurcation takes a straight line by the village of Ghanian and through the "k" of Ranikot, continuing in the same direction for about a mile, after which it was not traced. The gorge of the Hertoh beneath this band runs along the axis of the Trias anticlinal, which continues from near Kalapani staging bungalow up to Keithur, when it in turn bifurcates and uncovers the underlying slates which pursue a course up the north-east branch of the Hertoh river to the great gap between the Tandiáni ridge and the ridge going towards Sichar peak, 8,645 ft. The two bifurcations of the Trias continue, respectively, one along the ridge towards Sichar and the other under the north-west crest of the Tandiáni ridge. I was unable to visit Tandiáni myself, and entrusted the working out of the section which follows to Babu Hira Lal.

Tandiáni sections.

Babu Hira Lal reported that, as regards the Trias limestone, the band going by Keithur after ascending the Keithur spur passes south of the gap between the Tandiáni and Sichar ridges. It then continues round the north end of the Tandiáni ridge and out along its north-eastern spur for a mile or so beyond the station. Its outcrop then returns along the eastern face of the Tándiani hill, keeping to a uniform position above the slates all the way round from the north of Tandiáni to the hill above Undree Seree, from which point it spreads out a little more down the north-eastern slopes of Musta peak in the direction of Puniali and Nunhiali, after which the outcrop bends round again to the south-east, and cuts the southern spur from Musta east of Jhafur and so down to the neighbourhood of Sirbunnuh.

It will thus be seen that the station of Tandiáni and its commanding summit is due to the presence of Trias limestone capping the great ridge in a general way. But the surface of the station is relieved to a considerable extent, and moulded into softer outlines than would otherwise ensue by the presence of the Spiti shales,

retained in the folds of the Trias limestone, a wide band of them extending from the band near Kalapani staging bungalow. But whilst the eastern side of the ridge is a great scarped wall of Trias limestone, the north-western and western slopes are dip-slopes in a general way, the section from the 8,848 ft. peak in a north-westerly direction down to the great gap being as below, fig 14.

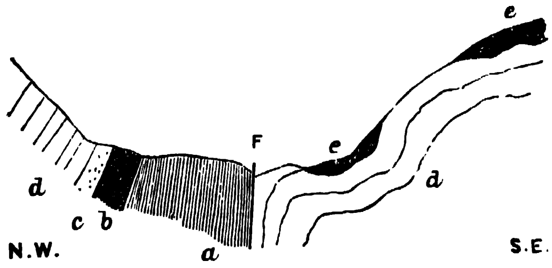


Fig. 14.
e—Spiti Shales.
d—Trias Limestone.
c—White Quartzite. } ? base of Trias.
b—Purple do.
a—Slate Series.

In it the Trias dip-slope, modified by minor folds, and with the Spiti shales occupying hollows, meets the slates in the great gap, and is divided from them by a fault approximately vertical. A similar section from the more southern part of the Tandiáni ridge to a point a little north of the Kalapani bungalow is next given below, fig. 15 :—

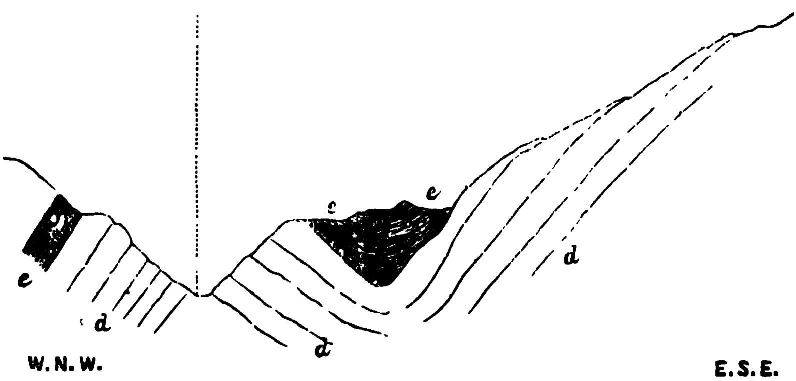


Fig. 15.
e—Spiti Shales.
d—Trias Limestone.

In this section the slates are not visible, but a dip-slope in the

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Trias of the right-hand portion of the section is modified by a sharp synclinal enfolding the Jurassics near the staging-bungalow, and this is followed by the anticlinal of the Hertoh river.

Tandiáni, like all the hill stations along the great watershed in this part of Hazara, is an assemblage of temporary wooden houses erected for use in the summer months only, and is completely deserted during the winter when these high crests are draped in a mantle of snow, relieved only by the tall straight stems of the Paludar and Biar. The houses are dotted about on the undulating surface afforded by the Spiti shales, but the latter are cut down here and there by streams to the upper surface of the Trias limestone. Such exposures display the basal bed of the Spiti shales as a good strong ferruginous layer, 1-6 ft. thick, the thicker portions lying in the hollows of the Trias limestone.

Sections along the scarped edge of the Trias on the east side of the station show the limestone underlaid by the bed of quartzite, which I have before explained is its normal base when it directly overlies the Slate series without the intervention of the Infra-Trias.

The gap north-west of the Tandiáni ridge (see fig. 14) exposes on its northern side the Trias of the Sichar ridge similarly underlaid, but by both white and purple quartzite as much as 50 ft. thick. In none of the sections round about Tandiáni is there any trace of Infra-Trias limestone or of the basal conglomerate. The presence of the purple quartzite, just referred to, is a little puzzling. It may either belong to the base of the Trias (as seems the more probable) or to the Infra-Trias. In the latter case there must be an unrecognised break between it and the white quartzite, which is usually found at the base of the Trias when no Infra-Trias is present.

Along the line of the word Undree Seree on the map the great mass of the Trias limestone, descending in great forest-covered dip-planes from the south end of the Tandiáni ridge, receives above it the Jura-Cretaceous and then the Nummulitics. The outcrops of the former extend from the exposures near Kalapani due east to a marked gap in the main ridge, and they then pass round to the

eastern side of the ridge allowing the Nummulitics now to constitute the crest of the main ridge the rest of the way to Musta. For some distance south of the "S" of Seree the Jura-Cretaceous band follows a hollow between the main ridge and a little spur formed of Trias on the "r" of Seree, whilst beyond, the eastern slopes of Musta, though deeply wooded, embrace a normal section from the Slate series through the Trias, Jurassic, and Cretaceous, up to the Nummulitic. About one mile north of Musta the Cretaceous band, in the form of a sharp anticlinal (already referred to in the neighbourhood of Hariala in the Hertoh river), passes by a deep gap to join up with the band on the eastern side of the main ridge.

Along the Sichar spur the base of the Trias was followed as far as the "T" of Telkandi; but beyond this no exploration was made by Hira Lal; so that the hill-spurs in that direction, which are rugged and precipitous, have eluded our survey on the two occasions when our party were in the neighbourhood. (See p. 126.)

Sections in the Slate series N.E. of Tandiáni along the Booee, Luree, and Silole streams.

The sections noted in the margin were approached from the Koonhar river as a a base of operations. The head-streams of the Booee N. drain down from Phoot hill (6,654 ft.). Edwards explored the junction between the Infra-Trias and the slates. He found purple limestone and sandstone and shale belonging to the former, but the basal conglomerate was not visible. Their dip was 70° W.N.W. Some pale blue-grey slates in the Slate series were pyritous, the small cubical crystals of iron-pyrites being $\frac{1}{8}$ inch across. Along the Booee N. and on the hill-spurs round about the uniform slate hills present a very bare appearance, except for the low jungle of Sunhetta and *Justitia adhatoda*. The general strike of the cleavage of the slates is N.E. or N.N.E. and the dip N.W. or W.N.W., and the cleavage generally coincides with the bedding, but not always. It may even occur at right angles to it. The Koonhar river where the Booee N. joins it, and up-stream towards Gurhee-Hubeebooluh is a deeply cut gorge of a distinct V-shape, as opposed to the U-shaped valley at Gurhee-Hubeebooluh. Recent river-gravels may be seen at various heights on the sides of the Koonhar valley,

but their higher occurrences are in local patches, and not in a well-defined terrace or bed. Up the Booee N. well-worn river-boulders extend up the hill-side to just beneath the village of Pul, which I estimate is about 1,500 ft. above the present bed of the Koonhar. A well-defined terrace, however, occurs along the Koonhar valley above Booee, averaging 200 ft. above water-level, and this evidently corresponds to the similar gravels at the Rutwala junction, and near Gurhee-Hubeebooluh. On hill-sides as steep as 40° the slates are in a rapid state of disintegration and decay. Land-slips and scree-surfaces abound. In consequence the gently sloping ridge-crests are the only places where cultivation is attempted and all the villages are situated in such places.

The Luree stream drains down from Tandiáni, and is a counterpart of the Booee stream. Its journey down its little steep-sided ravine is a monotonous progress through the slates, with only the intervention of a few thin limestone bands a few feet thick near its junction with the Silole N. The hill-spurs descending towards the Luree stream from Tandiáni are just like those near Booee. Somewhat broad along their crests, these spurs are visibly contoured by innumerable fields with their banks and retaining walls, and with minute hamlets dotted along their course. The general colour of the slates is grey, and with a bright sheen upon their surfaces. Towards the Silole N. they become slightly more arenaceous. Cleavage dip as before 60° N.W.; in many cases it is distinctly across the bedding, but generally it is in the same direction.

The Silole N. is an extremely deep-cut gorge in its lower part, impossible to cross with pack animals (*i.e.*, mules) any great distance below Beerun Gulee, near which it takes its rise.

On the whole there is scarcely anything of interest to chronicle in this part of the Slate zone. Communication between village and village must be made entirely on foot, save for the apology of a bridle-road along the Koonhar valley. The river-beds in dry weather are the most direct and level routes to follow. Baggage animals can be taken along certain lines of country, but the difficulties are very great on account of the disintegrating character

of the steep slopes. It behoves the traveller, therefore, to arrange his own roads, and even turn engineer on occasions.

Sections south-east of Huveliyan and Rujoeeuh.

We must now turn back along the strike of the Slate zone to that portion of it lying to the south-east of Huveliyan and Rujoeeuh on the Dore river, from which, as a starting-point, I shall now describe a set of strike areas forming the south-eastern portion of the Slate zone.

Sections near Sariwali, Kotluh, and Oochar.

About $2\frac{3}{4}$ miles due south of Huveliyan appears the thin end of a wedge of Trias limestone, let in among the slates by a fault on its north-western side. It is a mere strip, $\frac{1}{8}$ mile wide, and about $\frac{1}{2}$ mile long. In the direction of its strike towards the north-east this band is interrupted by a mile of alluvium, after which another exposure of the same band appears as a short low ridge, $\frac{1}{4}$ mile long, followed almost immediately by a much longer outcrop of the same band, which also widens slightly, in the direction of Kotluh. In addition to the Trias limestone exposed in the last outcrop, a representative of the Jura-Cretaceous band, and a trace of the Grey limestone, strike diagonally across the run of the faulted mass. A view and section of this band is given below, fig. 16:—

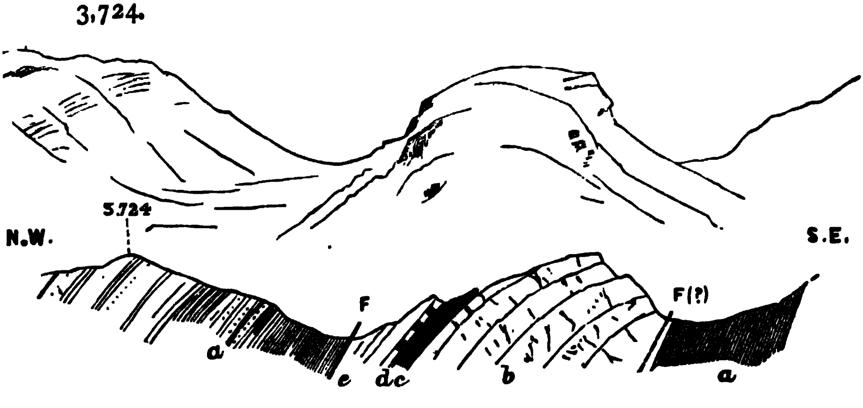

Fig. 16.

e—Grey Limestone.
d—Cretaceous.
c—Spiti Shales.
b—Trias Limestone.
a—Slate Series.

On Wynne's unfinished map of this part of the country he marks the limestone band as one belonging to the Slate series. The presence of the Jura-Cretaceous and Nummulitics in regular order superposing the main rib of limestone, not to mention the petrological character of the limestone, are sufficient to shew that the truth is as indicated above. At the same time it must be remarked that Wynne recognised the secondary age of some of this limestone as is shewn by his remarks (Rec. G. S. of I., Vol. XII, p. 121) where he describes having found much-crushed ammonites among it (see *ante*, p. 18, and Manual of the Geology of India, 2nd Edn., p. 116). The fault on the north-west side of the wedge of younger rocks is self-evident, but that to the south-east may only be locally present. At Sariwali it must be absent as Hira Lal reported the presence of the white quartzite which is the base of the Trias in this line of strike.

Along the same line in a north-easterly direction there is another small mound of Trias limestone surrounded by alluvium, and then a wide stretch of alluvium with two deeply cut-down streams named the Godawala N. and Huriala N., respectively, after which two prominent hills near Oochar expose Trias limestone and the Jura-Cretaceous band in a wider outcrop than hitherto. The position and lie of these are indicated sufficiently well in the view south-west along the Slate zone (Pl. 9).

Section near Mohar, 5,815 feet, Deewal village, and north of Naruh police station.

Leaving this strike fold of younger rocks among the slates, although we can at once see from the map that the Seree and Juswal ridges carry on the same structure in a north-easterly direction, we must now go south towards the southern boundary of the Slate zone, and by the Deewal pass ascend the rocky height of Mohar, 5,815 feet, which is a mass of Trias limestone presenting a rough and broken face to the north-west. To the south-east it reveals a well-exposed scarp with the slates below it. Mr. Edwards found the base of the Trias here to be (1) yellow, purple and variegated calcareous shaley layers with a bed of purple grit in the middle of them one foot thick, and (2) quartzites, some of a light purple-grey and others white with minute strings of red, of a saccharoid texture, and

weathering dirty orange-yellow. Although there is no trace of a conglomerate which might be referred to the Infra-Trias basal conglomerate, it seems possible that the yellow, purple and variegated shales may represent a portion of the Infra-Trias sequence. After about 500 feet of Trias limestone as he ascended the hill Mr. Edwards found Spiti shales and Gieumal sandstone appearing at a little flat place on the ridge about the position of the last "h" of Chumnukkuh, thence striking west-by-south along the north face of the hill in a kind of trough to the north-western spur of Mohar on the "m" of Chumnukkuh. The dip is 60° north-west, and there must then be a refolding back of the Trias beds between that line and the base of the Trias on the "h" of Mohar.

The mass of Trias forming this hill divides into two branches about the position of the "D" of Deewal, one branch in a more or less disjointed way going E.N.E. from Kiyaluh village, and one following the Deewal ridge to a little north of the pass, and then continuing as a constricted band towards Kalabagh. At the point, to the north of the pass, where the road to Mari mounts the ridge, the sandstone forming the base of the Trias is a very pronounced arkose, almost indistinguishable from a granite in the hand-specimen. The same was found about the "D" of Deewal by Edwards.

The hill north of Naruh police station, unnamed on the map, presents very similar features to the hill just described, with the exception that the Jura-Cretaceous fold includes also a fairly large slice of Grey limestone coming above it. Taking the section across this hill in detail, beginning from the Naruh police station, we find first of all next to the great fault which divides the Slate zone from the Nummulitic zone a thin band of slates striking N.E. by E. They are all of a greenish grey colour with bronze-coloured joint surfaces and much splinted. Hira Lal found that the base of the Trias resting upon the slates along this line of strike was the same as near Deewal, and it indicates, therefore, a normal overlie between the unconformable Trias and the slates.

Ascending from this line of junction towards the hill-top in a

northerly direction, the section is entirely in the Trias limestone, shewing bare scarped edges to the climber, which strike along the general direction of the ridge towards the " M " of Mohree Budbhain. At the top of the hill the beds flatten out with a few minor folds. A little way below the summit, along the spur going W. by N., traces of Gieumal sandstone and Grey limestone appear, but the rest of the section can be better followed in the stream-bed which goes from the gap north of Naruh police station towards Dhunuk. Along that line the Spiti shales are feebly exposed, lying in a slightly inverted position against the Trias, which is here full of indistinct remains of shells. The Spiti shales are followed by Gieumal sandstone, then by the Cretaceous band, and then by Grey limestone. The Grey limestone continues in force down to the point due north of the first "h" of Kurchh in the stream-bed. There must then intervene a fault, for the next rock is a thin strip of slates followed by Trias limestone once more. Whilst the outcrop of the latter passes round to the north-east to join up with the Trias of Mohar hill, the thin band of slates passes by a series of gaps on the hill-spurs to join up with the slates of Deewal. Throughout this traverse the strike has gradually been turning round from E.N.E. to N.N.E. Trias limestone, so far as exposures allow one to judge, continues to the Nalan river; but the recent gravels of that stream conceal its relation to the slates beyond. The following rough sketch section through the top of the hill, north of Naruh in a W.N.W. direction, will generally indicate the structure of this small outlier of the younger formations upon the slates :—

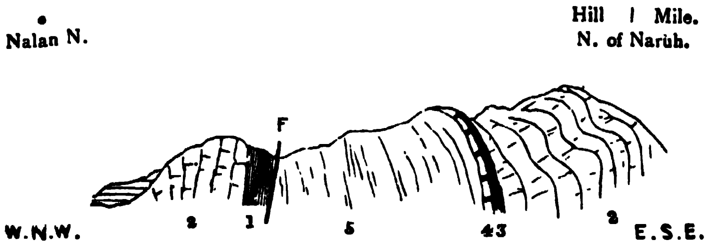

Fig. 17.

5. Grey Limestone.
4. Cretaceous.
3. Spiti Shales.
2. Trias Limestone.
1. Slates.

Sections near Juswal, Tope hill, 6,545 ft. Bagh and Juggiyan.

If a line be drawn from the Dore river near Kihal to Deewal it will be seen that to the west and south-west of that line nothing but low hills in the slates, with scattered and broken outcrops of the younger formations, are present, whilst in the opposite direction the hills increase in height and steepness, their separate spurs coalesce, and the outliers of the younger formations continue in a more connected way commanding the crests of many of the N.E.—S.W. ridges. The thin broken fold of these rocks near Kotluh, described in the last paragraph, we have already seen to shew signs of spreading out and dividing near Oochar, and we now see that in the neighbourhood of Juswal one band goes off along the Seree ridge to Jhan and Tope hill, 6,545 feet, thence spreading in a south-easterly direction towards Bagh and beyond, whilst another passes by the little hill south of Kihal along the low ridge through the "s" of Juswal, after which spreading out still more at Sudruth it occupies the W.S.W. buttresses of Tope hill and joins up once more with the other band (see view looking north-north-east from above Juswal village, Pl. 7). South of the line of strike above indicated there starts at the village of Garhee a previously unrepresented faulted mass of the younger formations embracing the usual sequence from Trias to Nummulitic. This continues up to and beyond Juggiyan; whilst to the south of this again, the outliers of Mohar and the hill to the south-west of it are only represented in a north-east direction by narrow bands of Trias limestone.

Sections near Juswal.

Juswal village lies in the Dore valley over against the towering crags of Sirban. It is situated directly in the line of horizontal section No. 1, by the aid of which I shall now attempt to describe the geology of the locality. To start with we must first cross the Dore river and mount to the little hill between Juswal and the main mass of Sirban, which has hitherto been neglected. The deep bed of the Dore with its high gravel cliffs, together with the little hill just referred to, are present in the sketch

of the gravels of the Dore (Pl. 11) as seen from a low elevation, whilst the same, as a more distant view and from a much higher elevation, are seen in the view west along the Slate zone (Pl. 9). This little hill, a sort of outwork from the Sirban mass, and its twin continuation a mile further north-east, suffered rather summary treatment in the map with Waagen and Wynne's Memoir, being coloured entirely as slates. Horizontal section No. 1 shews it to be really a slightly broken synclinal in the Trias, carrying in its trough a regular sequence through the Spiti shales and Cretaceous up to the Grey limestone. The fold is almost symmetrical, but there has been a slight tearing along the south-eastern exposure of the friable Spiti shales. It must be understood here and elsewhere that the small scale of the map has necessitated the drawing of the bands of rock here all of equal breadth, a mechanical difficulty unavoidable. The horizontal section alone gives the proper proportions of the strata. The normal N.E. - S W. strike prevails. The continuation hill to the north-east only exposes the north-west half of the synclinal, which is also inverted, and, with a return bend towards the north-west, presents the appearance of a folded flexure, though it is most likely that the appearence of inversion, along the south-east face of the hill where it overlooks the Dore river (the exposures are much obscured by river-gravels), is one due to secondary slipping of the hill-side, and not to the original impress of the folding of the strata.

North and north-east of the "J" of Juswal there are two little hill-spurs projecting from the long Trias-capped ridge, which travels S.S.W. from the "s" of Juswal. These little spurs embrace a Jura-Cretaceous and Nummulitic sequence in several very small folds impossible to render on the map, but which are shewn in the horizontal section, which is made to go a trifle out of its course to include one of them. These small folds may be understood as a corrugation or packing-up of the strata along the plane of weakness between the Spiti shales and the massive Trias limestone beneath. The Trias-capped ridge to the south-south-west has its base formed of slates,

the cap of limestone dipping slightly east-south-east; but the junction between the two rocks, especially on the west side, is not well exposed. It is even possible that there may be a small remnant of the Infra-Trias left between the two. There are certainly blocks of it in the mixed talus and gravel at the foot of the hill. South of this spur, and forming a little isolated hill between Kihal and the Shakra N., the Trias, as it reposes on the slates in a similar way to that of the ridge just mentioned, exhibits its base in a scarp on the north-west side of the little hill. The lowest layers of the limestone are fossiliferous, and between it and the slates comes a band of white coarse quartzite, variegated with red layers. The south-eastern face of the hill is a dip slope.

High ridge south-east of Juswal.

Leaving Juswal and taking a course south-east up the high ridge in that direction we pass across a very perfect section from the slates to the Nummulitic limestone. The ridge is sharp and steep on both sides, giving almost an equilateral triangle in section. The various formations lie in courses one above the other and pass completely through the ridge. Without regard to minor foldings, the general run of the crest of the ridge is along the axis of a shallow synclinal (see horizontal section No. 1). After passing over the Slate series, the foliation dip being generally south-east or east-south-east, we meet with the Trias in bold crags running as a rampart all along the hill-side, but breached in a few places where streams of disintegrated Spiti shales have slid down the mountain face. The thickness of the outcrop of the Trias limestone exposed along this line is very variable. This may partly be due to the eroded surface above on which the Jurassics lie, but I am inclined to think that the chief reason is to be found in the line of weakness between the thick-bedded massive Trias limestone and the thin-bedded slates at their base, which has allowed the latter to be squeezed out from underneath them in places along several small fault-lines. It is very evident that if a course be taken up the ridge due south-east by south from the "w" of Juswal we pass over a comparatively insignificant cliff of this limestone, not more that 250 feet,

whereas further away to the south along the run of the ridge the crags stand up in very lofty precipices over 500 feet in height. This band of Trias runs from the south-west end of the ridge near Guhoruh, where it is in strike continuation with one of the little hills near Oochar, all the way along the north-west face of the ridge towards the head of the glen above Gool and west of Jhan, when it sweeps round towards the Sudruh buttress of the Tope hill. Besides the few slips of Spiti shales down the slopes, which here and there break the continuity of the outcrop, there is one rather large slip of Nummulitic limestone, at a position due west of Jhan, and represented on plate 7 looking north-north-east from above Juswal. This slip completely conceals the outcrop of the Trias, and by its gentle slope forms a natural and easy track up to the villages in that direction. This detail could not be recorded on the one-inch map. Above the Trias the Spiti shales, all along this side of the ridge, shew a beautifully characteristic development. The Trias surface on which they lie is an irregularly flat platform which follows round the top of the Trias crag. Here can be studied at leisure, as well as near Tanakki or at Tandiáni, the unconformable overlie of the Jurassics with the boring mollusca imbedded in the hard floor. As below near Juswal, there are slight minor corrugations of the Infra-Nummulitic rocks above the Trias and along the line of weakness furnished by the Spiti shales. One such is shewn, plate 7, in the view north-north-east from above Juswal, and others occur near Jhan. They were all too small to be represented on the map. The normal sequence through Gieumal sandstone, Cretaceous, Grey, and Nummulitic limestones now follows as the hill-side steepens to the top of the ridge. At about 2,000 feet above the Dore river, between the Grey and Nummulitic limestones, there is an exposure of the variegated sandstone and carbonaceous band which, on excavation, yielded a seam, 17 feet thick, of coal and carbonaceous shale in varying proportions (for details see Appendix , page 288). Presently the top of the ridge is gained and over the other side we look down a still steeper declivity, a small notch in the slope some way down proving to be the Spiti shales

with the platform of Trias underneath. The coal-band was not found on this side.

From the top of the ridge a splendid view is obtained down the Slate zone of the Dore valley, and with the south face of Sirban standing out clear before us in all its details. I have attempted to represent this in pl. 9. The whole breadth of the Slate zone is comprised in that view, the pink colour to the right indicating the Crystalline and metamorphic zone, and the burnt sienna tint to the left representing the Nummulitic zone. Besides Sirban hill, which is the chief object in the view, Mohar, 5,815 feet, appears near the extreme left, and below it in the nearer middle distance the tail end of the ridge on which we are standing, and to the right of it the Oochar group of little hills, with the Kotluh continuation a little beyond in the further middle distance. The central parts of the view are occupied by the gravel terraces and alluvium of the Dore valley, with the river-bed winding its sinuous course away into the distance by Hureepoor. The Abbottabad plain is partly visible to the right. No one but a geologist, who has plodded over every foot of the country and knows it by heart, can appreciate a panorama such as this in the wonderfully transparent air of the Punjab, where each twist and turn of the formations can be picked out and recognised by some slight difference, which the uninitiated would fail to see.

The same ridge near Jhan.

We can easily make our way the whole length of the ridge before us stretching away to the Tope hill. At Jhan (there are two villages of this name not far apart) the section across the ridge is practically the same as it is across the ridge south-east of Juswal. There are as much as 200 feet of Jura-Cretaceous lying on a marked platform of Trias on the western side of the ridge and gently dipping in towards the hill. They are followed by Grey limestone, but the fluctuating dip in this soon brings the Spiti shales, etc., into view again. Just above the eastern Jhan the exposure is but a small one and none of the underlying formations are seen, for the dip once more plunges

into the ridge, and the Spiti shales disappear beneath the Grey limestone. I may here mention an outcrop of the coal-bearing sandstone lying above the Grey limestone at a point on the ridge about ½ or ¾ mile south of the eastern Jhan, and it is covered by Nummulitic-bearing limestone and shales in the neighbourhood of Seree on the ridge. The Nummulitic limestone here is often thin-bedded, but it is not of the marked concretionary habit prevailing further to the south. The angles of dip are steep, 40°—60°. The whole of the ridge is bare of trees, except for a few wild olives at ziarats, and scrub jungle of *Adhatoda* and Ber (*Zizyphus*).

At Jhan the second band of the Jurassics, which makes its appearance by overfolding, takes a north-easterly direction and gradually becomes accompanied on its south-eastern side by a portion of the Trias limestone brought up by a fault which strikes north-east from Jhan. This narrow strip of Trias, with the overlying Jura-Cretaceous, occupies a position under the southern crags of the final ridge of the Tope hill, the dip being in towards the hill at 35°. It presents the same characteristics as the more distinctly visible outcrops on the western face of the ridge.

Tope hill.

The ridge from Jhan ascends gradually to the Tope hill. From its culminating summit, 6,645 feet, which is composed of the upper Nummulitic limestone, there are given off three main side-spurs or buttresses, besides the the ridge along which we have approached the mountain. One of these goes west and south-west to Sudruh, another goes north by Khun to Seergah and Deesal, spreading out as it does so; while between this buttress and the last a steeply cut-back ravine is present. Lastly, another spur is given off east in the direction of Bugnotur. Between it and the Deesal spur precipitous cliffs and ravines exhibit some fine folding of the strata when viewed from the Abbottabad-Bugnotur road. The thin faulted exposure of Trias and Jura-Cretaceous outcropping north-east from Jhan cuts the eastern spur some way below the summit of the hill at the second "6" of 6,645 on the map, but the Trias is lost at this point, and there is only a trace of

the Jura-Cretaceous. The same outcrop continues down the ravine to the north for some way, the dip of the beds flattening out. The outcrop follows round the hill to Khun, whence it returns by the Deesal spur and the north-western cliffs of the mountains to cut the Sudruh spur in a bold tooth of rock, and joins up with the outcrops on the western side of the Jhan ridge.

Section up the Khun-Deesal spur.

During the first part of my time in Hazara a great number of traverses were made on and about the Khun-Deesal spur in connection with the coal outcrop at the Public Works Department mine below Deesal in the valley of the Dore. A summarised section up this ridge from the Dore river to the 6,645 summit is as follows. As shewn in the sketch-section accompanying my preliminary note on the coal-seam of the Dore river (Rec. G. S. of I., Vol. XXIII, pt. 4, 1890, p. 267), the lowest part of the spur is an inverted series through the Nummulitics, coal-bed, Grey limestone, Cretaceous, and Gieumal sandstone, to the Spiti shales. At this point, which is a little below Deesal village, the four last rock-stages are seen in a perfectly exposed section, which has so far embraced the middle inverted limb of a reflexed fold. Ascending to Deesal from this, we cross the edges of the beds in opposite order, *viz.*, Spiti shales, Gieumal sandstone, Cretaceous, and Grey limestone; the series dipping down the slope and forming the upper limb of the reflexed fold. At the same time it constitutes the lower limb of another reflexed fold; for a little further up the hill, between Deesal and Khun, a fine section in the Grey limestone shows the latter bent back upon itself, and another little ridge and gap shews once again an inverted series from Cretaceous to Spiti shales, and with Trias limestone in a not very thick exposure forming the basis of the ridge on which Khun is placed. This outcrop of Trias is continuous in a south-westerly direction with the Trias cliff on the western side of the Jhan ridge. Returning to Khun, we find the Trias limestone bent back very sharply upon itself dipping normally towards the Tope hill, under which it passes to reappear, as already stated, in the outcrop north-east of Jhan. The

section above this through the same Jura-Cretaceous and Nummulitic sequence is in normal order to the top of the hill.

Of the bands, which we have traversed over in this ascent, the first outcrops of the Nummulitics, coal, and Grey limestone continue south-west to the Sudruh spur, crossing the intervening ravine, whilst in a north-easterly direction they cross the Dore river obliquely and join up with the outcrop of the same formations south of Mohar (see section through Bunyan hill from Gulee to the Hertoh river). The inverted Jura-Cretaceous, next in order, forms an ellipse of outcrop about 2 miles long, completely encircling the broad Deesal end of this spur of the mountain and coinciding on its south-eastern side with the next inverted outcrop of the same series below Khun; so that Deesal village is situated on a small elliptical outlier of the Grey limestone. At each of its ends the ellipse of the Jura-Cretaceous rocks continues as a single band of outcrop travelling N.E.—S W.; that to the north-east crossing the Dore river in a nearly vertical outcrop and joining up with the Sirbunnuh band, and that to the south-west going by Seerguh to the Sudruh spur; that is to say, in these two directions the inverted middle limb only of the flexure has been preserved from denudation. The bands above this on this spur have already had their strike relations indicated.

Section up the Sudruh spur.

The Sudruh spur given off from Tope hill is of the form of a crook handle, with the inside of the bend directed southwards. Its north-western slopes opposite Dhumtour descend steeply to the Dore river, especially in their lower parts (the whole of Tope hill on every side is steeply cut away near its base). Just opposite Dhumtour a very black band of rock is seen in the river-cliff. This may be easily mistaken for a continuation of the coal-band of the Public Works Department mine. It is in reality an outcrop of the Spiti shales, of jet-black colour, which, with the underlying Trias and the overlying Cretaceous, proceeds south-south-west along the north-western edge of the hill to the neighbourhood of Juswal, when the Jura-Cretaceous bands curl round to form the end of the handle.

of the crook and return *viâ* Sudruh to Seergah. Thus the lower portion of the Sudruh spur is a synclinal fold in the Grey limestone and the subjacent Jura-Cretaceous, its south-eastern limb being inverted. The coal-bed along this spur was not traced by me. Above Sudruh towards Tope hill, after the Jura-Cretaceous band is crossed, we meet with a wide outcrop of Trias up to the point on the spur near the final ridge where the tooth-like rock of Trias is overlaid by the last normal fold of the Jura-Cretaceous and Nummulitic rocks. The structure of this spur is well seen in the view north-north-east from above Juswal. It is distinguished from the Deesal spur by not having any representative of the Deesal outlier of Grey limestone, for the reason that the upper limb of the sigmaflexure or overfold has passed above what is now the highest point of the spur.

Section down the eastern spur of Tope.

I have already alluded to the fault running north-east from Jhan which cuts the eastern spur of the mountain on the second "6" of 6645. This fault, which dies out below Jhan and is of small amount on the spur, becomes more important as it travels north-east down the steep crags between Deesal and the eastern spur into the gorge of the Dore river; for, north-west of the fault the sequence from Khun down to the river embraces every formation to the slates, whilst south-east of the fault the slates are excluded from the section and Trias limestone occupies the bed of the river. The gently descending part of the eastern spur below the fault is in the Nummulitic and Grey limestones, with a coal exposure a few hundred feet above Bandee, but the slopes steepen to the Dore in the direction of Bugnotur, and become convex. A dark line of fields, with sometimes the usual gap and ridge, especially marked at the northern extremity of the spur, indicates the Spiti shales and the underlying platform of Trias. The unconformable junction of the Spiti shales on the Trias, and the overstepping of the former across the edges of the latter are well seen here. The base of the Spiti shales consisting of a layer of martite wraps over the Trias like a stair-carpet. This line of Spiti shales may easily be found, and if from its position the eye is

directed across the Dore to a corresponding level on the Uzeezmung hill, a similar line of crag and gap may there be detected unfailingly indicating the same line of outcrop. A small cross-fault east of the "n" of Khun prevents the Jura-Cretaceous band continuing round to join up with the Khun band, and also drops the Nummulitics in that direction, so that they abut first against the Trias underneath Khun and then against the slates below that. In the opposite direction towards Bandee the Jura-Cretaceous band winds a sinuous course at a low level, until it ultimately joins up with the eastern band of the same rocks along the Seree ridge. Near Bandee a little complication occurs, the outcrop of Jura-Cretaceous gives off a process from the "n" of Jhan towards the "B" of Bandee, a sort of secondary fold of these rocks, and with two little hills of Grey limestone as outliers among it. The Trias, which follows in order below the Jura-Cretaceous on the eastern spur, has only a short thickness visible, and it is then cut off by a fault letting down the Nummulitic limestone.

We have now completed a brief stratigraphical sketch of the Tope hill. In its isolated and commanding position it is almost a counterpart of the Sirban hill. The narrow ravines on its northern, eastern, and south-eastern sides, together with the little pass at Bagh which links it with the great northern spur of Taumi, do not, however, throw it into such bold relief as the wide valley of the Dore near Huveliyan and Rujoeeuh and the broad Abbottabad plain do the Sirban mass. In horizontal section No. 1 (Pl. 3) the structure of the Tope hill appears above and behind that of the main section, which at this point passes considerably to the south-west of that hill. By means of it the descriptions given above will be readily understood.

Section near Bagh.

The stream which runs south-west from Bagh, and which lower down becomes the Shakra N., flows over the Slate series between high gravel terraces. At Bagh, however, which is placed on the little pass before mentioned, the slates become arched over by the Trias limestone, basal sections

of which may be seen with the beds dipping away from the pass on both sides. On the south-east this section is as follows:—

Ordinary Trias limestone.	
Yellow thin bedded marls . . .	6 feet.
Light red limestone	3 „
Brownish and blue limestone . .	10 „
Fine conglomerate	2 „
White and sometimes reddish quartzite	12 „
Slate series.	

Hill south-east of Bagh.

To the south-east of Bagh rises a hill composed of three small transverse ridges connected together, which give it the appearance of three separate summits. A section through the hill is given behind the main section in horizontal section No. 1. From it we see that the base of the hill is an outlier of Trias limestone above the slates, whilst the upper parts of the mountain are composed of grey and Nummulitic limestone. Between the two lies the Jura-Cretaceous band, which has evidently acted as a line of weakness, above and below which, the corrugations of the strata are not harmonious. The reversed fold-fault inserted on the map and indicated in the section near the middle of the hill is peculiar, because it follows the axis of an isoclinal arch in the Grey limestone and the trough of a synclinal in the Trias below.

The whole of the southern part of the Bagh hill is a simple outlier of Triassic and Supra-Triassic rocks, complicated by the corrugations and faulting to which I have referred; but to the north, in the direction of Maira and Bandee, the Nummulitic limestone alone is visible, plunging down to a very low level and continuing as a narrow faulted strip into the bed of the Dore river and across it to Tirati. Its appearance near Tirati is given in horizontal section No. 2 (Pl. 4), where its extraordinary position, wedged in between masses of slate and Trias limestone at so low a level, is difficult to understand.

The geology of the south-eastern portion of the Bagh-Maira hill was worked out by Mr. Edwards and Sub-Assistant Hira Lal. The stream separating it from the Bara Gali spur is cut out along the slates,

from which up to the top of the Bagh-Maira hill the ordinary ascending series of formations is unbroken, although the outcrops wind about and return upon themselves in a rather complicated way, due, on the one hand, to the folding of the rocks, and on the other to the three side-spurs and intervening streams which travel north-east, respectively, from the three summits of the hill. The section and map should suffice to make this structure comprehensible without further remarks.

The hill-spurs south-west of Bagh, across which the main section (horizontal section No. 1) takes its way, only consist of slates with a small synclinal fold of Trias capping them, a direct continuation of the same rock of the Bagh hill.

Section up the northern spur of Taumi.

From the southern end of the Bagh-Maira outlier, where there is a marked gap in the Slate series, the ascent up to the Taumi peak is a long steady climb, with a gentle inclination as a rule, though a few steeper slopes are to be met with. Forest begins almost as soon as the gap is passed at about 5,700 feet, and the whole of the rest of the way into the colder air zone in which the top of Taumi, 8,025 feet, lies is also through forest which can be seen to spread away, covering all the more elevated hill-tops in the direction of Bara Gali. The prevailing rock during the ascent is slate, but near the final peak there is a small patch of Trias limestone perched on the summit of a neighbouring peak. Taumi also owes its steep craggy summit to the presence in the Slate series of quartzite beds of a hard dark purple-grey colour, and in thicker and stronger beds than ordinarily occur with the slates. These same quartzites extend north-easterly and give to Mian-Jani-ki-choki its peculiarly elevated summit of 9,793 feet.

The most important interruption of the slates in the ascent up the Taumi spur is, however, a great faulted mass of the historical rocks from Trias to Nummulitic, the outcrop being two-thirds of a mile wide. The dip of the whole mass is north-west at angles of 50°—60°. In the Taumi direction it rests upon the slates in normal order, the base of the Trias consisting of the usual quartzites, and presenting in

a side-view an irregular waving line of junction with the slates, and descending with a steady dip of 60° as far as the eye can trace it among the side ravines without shewing any sign of returning upon itself. In the Bagh direction the Nummulitics are in contact with the slates, dipping down against them as in the hills north of Naruh, and as we shall see to be the case along the northern edge of the whole Nummulitic zone when we come to the description of it. A fault of considerable magnitude is, therefore, indicated on the north-western side of this block of formations. Every stratigraphical member of the normal sequence is present in this section, but on account of the forest and undergrowth no good exposures are available. Two noticeable gaps in the ridge are coincident, one with the outcrop of the Spiti shales, and the other with that of the base of the Trias.

This block of formations, wedged in by a fault on its north-western side, is continued along its strike in both directions. Towards the north-east it passes to the hill-spurs north-west of Bara Gali, and the marked gap between the slates and the base of the Trias is distinctly recognizable, even among the forest-clad slopes, as also is the grand sweep at an angle of 50° or 60°, which the massively bedded rock makes above the thin-bedded slates. The stream between Taumi and the Bara Gali spur has, however, cut through the younger formations above the Trias so that their outcrops bend aside, that on the Taumi ridge being stopped by the fault, and that on the Bara Gali spur shewing a returning bend upwards constituting a synclinal. This southern return bend also carries with it a thin outcrop of the Trias, which travels towards Bugnotur along the western flank of the spur overhanging the stream between it and the Bagh-Maira hill. In a south-westerly direction the same block of formations, bounded as before by the fault on the north-west, passes across the Juggiyan spurs obliquely, the Jura-Cretaceous band making a marked line in the vicinity of Juggiyan village. A little beyond this a cross-fault is inferred and has been inserted on the map on account of a section followed from the hill-top north of Chair down

the ravine to Bazgiran. The actual line of the fault was not located, its inferential existence depending on the fact that the one set of outcrops on the Juggiyan side do not coincide in direction with those on the Hoornaruh side. The steep dip angles take the outcrops over hill and ravine in a nearly straight course, so the above inference seems reasonably justified. The block of formations slightly narrows in the Hoornaruh direction, owing to the fault crossing rather obliquely over the edges of the Nummulitics, and near Garhee the latter and the Jura-Cretaceous band are both entirely cut off. Beyond Garhee, as has already been remarked, there is no representative fold of the younger rocks to correspond with this block of formations.

There is very little more that need be said with regard to the Taumi section. A view from the crest of the ridge down into the Samoondar N. reveals nothing but bare precipices and slopes of slate, quite devoid of forest as far as and a little beyond the bed of the stream where the Slate zone comes to an end and the Nummulitic zone begins. A more or less regular line of fields, on a slightly flattened portion of the slopes about midway between the Samoondar N. and Taumi, indicates a long thin outcrop of Trias limestone, which continues south-west to join up with the Deewal band, and north-east to near Kalabagh. The view south-west from Kalabagh (Pl. 5) shews the valley of the Samoondar, the junction of the Slate and Nummulitic zones, the steep bare face of Taumi, and the distant outliers of Mohar hill and the hill north of Naruh.

Sections near Sirbunnuh, Uzeezmung, Malsuh, Beerun Gulee, Bugnotur, Maira, and Mian-Jani-ki-choki.

Sections near Sirbunnuh.

It will be remembered that in describing the Tandiáni area, the Trias and Jura-Cretaceous bands east of Musta peak were dismissed with the remark that their outcrops turned south-east cutting the southern spur of Musta near Jhafur and so on to the neighbourhood of Sirbunnuh. At that place these outcrops pursue a straight and regular

course to the south-west, then cross the Dore river and join up with the Deesal inverted limb of the sigmaflexure. They disclose almost vertically bedded strata, which in the higher parts of the section are inclined to the north-west, and in the lower part to the south-east. It is examples of this kind which render it impossible to indicate the dip of such profoundly folded rocks by arrows inserted on the map. The almost vertical position of the Trias in this section gives one perhaps a very reliable estimate of its thickness, because faults and slips of the strata along joint and other planes could have but little effect, or perhaps none, in magnifying or reducing the outcrop of such a set of vertical strata. If this be a correct view, the thickness of the Trias here must average about 1,250 feet. The course which the outcrops take is directly down the hill-spur from Musta *viâ* Jhafur and Sirbunnuh to the Dore river, the hill-spur gradually lowering till its foot is buried in river-gravels. Round about Sirbunnuh the beds above the Trias are reflexed and repeated by fold-faults two or three times. They have already been referred to in describing the section up the Hertoh river. The junction of the Trias with the slates is a normal one, calling for no remark.

Section up the Dore river and Karati N. from the strike of Uzeezmung.

Between the Sirbunnuh spur and the Uzeezmung hill there is a deeply cut stream flowing into the Dore and draining parallel to the Sirbunnuh spur. The point where this stream joins the Dore is the normal junction between the Trias and the slates to the south-east, and the latter follow in a broad outcrop ¾ mile wide, and strike due north-east to Nuniali. Starting in this lowest member of the stratigraphical sequence our course up the Dore river and Karati N. is the ordinary route followed by travellers from Abbottabad to the hill stations dotted along the Gulees. A good bridle-road goes the whole way. There is no noteworthy feature about the slates in this exposure, except that as we pass across them they shew many signs of faulting, folding, and disturbance, with complete smashing in places as we near the next great faulted junction between them and the Trias. This line of junction cuts the river south-west of Uzeezmung and is in continuation with

the fault on the eastern spur of Tope. The Trias limestone, which we now enter upon, is in an extraordinary state of disturbance. The cliff to the north-east of the deep bed of the Dore is over 1,500 feet in height and a mile long as far as where the Tirati stream enters the Dore, and its steep and bare precipices exhibit fold after fold in the Trias limestone, especially confusing near the north-western faulted junction with the slates. I have attempted to render these in horizontal section No. 2, where the portion of the section alluded to above is seen forming the base of the great hill south of Uzeezmung. Far above our heads we know, from what we saw from the eastern spur of Tope, that the Jura-Cretaceous and Nummulitic rocks appear in normal order above this cliff, but the gorge of the Dore is much too steep and shut-in for us to see any trace of them from our present position in its bed. Still ascending up the river, and shortly after reaching the stream which joins the Dore from Tirati, there is very much disturbance of the Trias once more as a preliminary to another faulted junction between it and the little wedge of Grey limestone referred to (p. 163) as the north-eastern continuation of the Maira-Bandee outcrop (horizontal section No. 2 crosses the Tirati stream further to the north-east and shews this faulted wedge on the Uzeezmung side of the stream). It is barely ¼ mile wide, after which there is another line of faults dividing it from the next set of slates. The slate outcrop now entered upon continues the whole way up to Bugnotur, after which up the hill-side immediately south-east of the staging bungalow there is an abrupt contact of them with Nummulitic limestone to the south-east. The slates here are very much crushed and shattered, being in some places reduced to a fine powder, and the Nummulitics next them are also much shattered. To the south-west along this strike and across the Karati N. the fault gradually dies out, its place being taken by a normal ascending series through the Trias and Jura-Cretaceous, which form the north-western limb of the synclinal, noticed in the spur north-west of Bara Gali when ascending the Taumi section from Bagh. At one point on the "B" of Bugnotur there is seen for the last time a little

inverted anticlinal in the Jura-Cretaceous, where the Grey and Nummulitic limestones are bending over against the fault as drawn below.

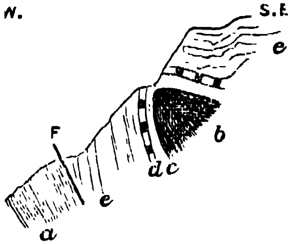

Fig. 18.
e = Grey Limestone.
d = Cretaceous.
c = Gieumal Sandstone.
b = Spiti Shales.
a = Slates.

In the road-section nothing is seen of this arrangement, it being as given in horizontal section No. 2 (Pl. 4). The Nummulitic and Grey limestones are first thrown into alternating undulating folds, and a bed of oolitic iron ore 4-5 feet thick, which I think is the representative of the variegated sandstone elsewhere containing coal, separates them. A similar rock was noticed on the Seree ridge in apparent connection with the white and variegated sandstone of saccharoid texture in which coal was actually found. After numerous undulations of this sort we come to a steady inverted dip in the Grey limestone, which forms the ridge north-north-east of the "r" of Karati. This is followed by the Cretaceous rock *in situ* on the road, and by indications of the Spiti shales in the side-stream to the north-north-east. This Jura-Cretaceous band, as it is hardly neccessary to point out, is a continuation of the south-eastern limb of the synclinal of the hill-spurs north-west of Bara Gali. Gaps on the ridges in both directions mark the outcrop of these shales, and between them terraces of fields with a dark-coloured soil follow their course among the dense forest of Biar, Oak, and Chir. The next set of cliffs by the road-side are in the Trias limestone, also in a slightly inverted position for a short distance, and then in subsidiary folds, as shewn along a corresponding line of country in horizontal section No. 2 near Maira, until finally they are found resting still in an inverted position against the slates. The line of junction is extremely well marked, and the great slabs of well-bedded Trias descend in magnificent curves from the hill above to the stream-bed. Many of them are covered with vermicular markings, not unlike the *Spongia paradoxica* of Hunstanton, England, and are doubtless of a concretionary nature. The base of the Trias here is fossiliferous and has been

described (stratigraphical elements, chap. II, p. 29). The following is a section with the fossiliferous layers indicated. The spot was marked by Wynne on his unfinished map.

Ordinary Trias limestone.	
Grey shales and marls with imperfect fossils	8 feet.
Limestone with fossils	10 "
Fine pebbly layer	1 foot.
Shales	1 "
Quartzite—about	12 feet.
Slate series.	

The section will be seen to bear a considerable resemblance to that of the same horizon near Bagh. If we leave the road and climb a short distance up to the ridge to the east along the line of the base of the Trias, we reach the marked indentation on the ridge overlooking the Kula N., and can follow perfectly by the eye the same line as it strikes down into that stream and crosses it to the Maira side-spur from the Mian-Jani ridge, which it divides immediately under the village of that name (see horizontal section No. 2). Allowing the gaze to travel down the spur from Maira towards Jhootmung, it naturally selects some darkly coloured fields for the position of the Jura-Cretaceous band.

Section up the Kula N.

The Kula N. in its upper parts among the slates, where it drains down from the great Mian-Jani peak, is a wild open grassy valley, bare of forest on the Mian-Jani side. But below Maira the stream has cut for itself a deep and rocky channel with rugged side-spurs of limestone, first of Trias and then of Nummulitic, descending into it and covered with dense and beautiful forest of Biar, Chir, Oak, Barungi, etc. Our endeavour to penetrate up this valley from Dhukkee was frustrated by the difficulty of the narrow path, which, having broken away in a precipitous place, compelled us to return.

Section up the stream from Tirati.

The stream from Tirati opens into the Dore by a vertically walled cañon in the limestone, only a few feet wide, along the bed of which it was necessary to wade for a considerable distance. The Abbottabad

road crosses it by a wooden strut-bridge at a height of about 60 feet. The gorge meanders along the outcrop of the Grey limestone and Jura-Cretaceous, and in so doing crosses several times at different places both of the faults on each side of the wedge of these rocks before reaching Tirati where the stream divides. The hill just south of the "l" of Malsuh shews that the Trias has again returned to its normal position in contact with the slates, both series being practically vertical, and much folded in extended isoclinal folds. We may assume, therefore, that the narrow wedge of Grey limestone and Jura-Cretaceous rocks along which we traversed has come to an end by the junction and dying-out of the two nearly parallel faults which bounded it. The stream section above Tirati is, however, far from clear as to the details of the process.

Section from near Phulkot to Sirbunnuh.

From the last position at the north-eastern end of the wedge of Grey limestone, the hill-side above to the north-west shews, by the presence of a village among dark-coloured fields a little east of the "g" of Uzeezmung, that there is a sharp fold of the Spiti shales among the Trias on the slope. Travelling up across this ridge *viâ* Malsuh, and across the intervening ridges and spurs to Sirbunnuh, we pass over sections which may be summarised in the sketch-section which follows. The pathway along which my party travelled is a steep and difficult one, our laden mules only with the greatest trouble being able to pass some of the rotten disintegrating spurs of slate. Comparing the section below with the structure of the hill south of Uzeezmung, as depicted in horizontal section No. 2, we see that the contorted and peculiar folding of the Trias and superincumbent rocks of that hill are replaced in that section by some very pretty examples of faulted sigmaflexures, involving all the rocks in stratigraphical sequence from the slates to the Spiti shales. To follow out the change the map must be consulted in conjunction with the sections. It will then be seen that the *Supra*-Trias rocks, south of Uzeezmung, are in the form of an irregularly elliptical outlier. The Grey limestone forms the top of the main ridge as far as the "B" of Bhungoor,

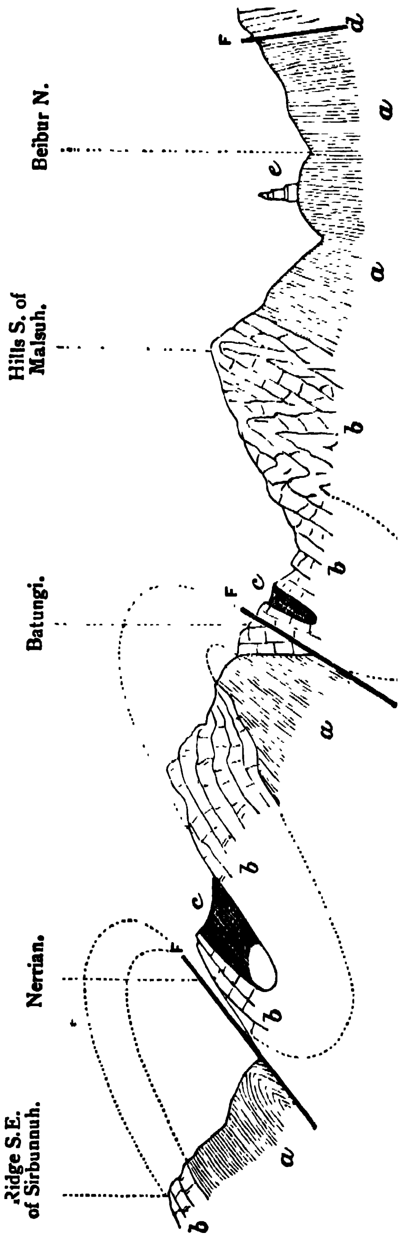

Fig.

ra

d = Grey Limes

c = Spiti Shales.

when a gap in the ridge allows the south-eastern outcrop of the Jura-Cretaceous band to change over from the hill-side facing Bugnotur and to take a northerly direction V-ing down a side-stream towards Nerrian, where it meets the north-western outcrop of that band, after which the two proceed as a single narrow outcrop for about a mile in a north-easterly direction and then die out. This is the little fold in the Spiti shales seen to the left hand of the sketch-section (fig. 19) and occupying the trough of the left-hand sigmaflexure. This pinched-up fold in the Jurassics is, therefore, all that is left of the wide

outlier of the Jura-Cretaceous and Grey limestone, capping the great hill south of Uzeezmung and represented in horizontal section No. 2. It is somewhat analogous to the long thin outcrops, extending north-east and south-west respectively, from the Deesal ellipse in the same rocks (see Tope sections). East of it the thinned-out middle limb of the sigmaflexure in the Trias, the low-dipping thrust-plane or reversed fault bounding it, followed by the slates, and the Trias limestone of the ridge south-east of Sirbunnah are strike continuations of the similar sequence of outcrops referred to in the section up the Dore. In the neighbourhood of Batungi the sketch-section represents another sigmaflexure of which there is no trace in horizontal section No. 2. Along the arch of this reflexed fold the slates which begin to protrude through the Trias a little north of the "g" of Uzeezmung appear, and they continue increasing in the width of their outcrop towards Beerun Gulee. South-east of the slate outcrop there is a broken or torn middle limb in the Trias on the "i" of Batungi, followed by a narrow band of Spiti shales in the trough of the fold. In the cliff-section, north-north-west of the "M" in Malsuh, the band is very narrow indeed, but it expands considerably in the little gap north of Malsuh village. In the first position, where it is extremely narrow, or almost reduced to nothing by compression of the lips of the Trias limestone, it approaches very nearly to what is called by Heim and Margerie "*noyeau synclinal detaché par étranglement*" and must be imagined as of the following structure (fig. 20). After

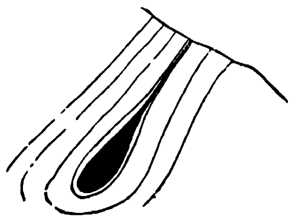

Fig. 20.

the Spiti shales the trough-limb of the sigmaflexure to the right is formed of Trias limestone, repeated in one or two minor folds and rising into the high ridge south and north of Malsuh, beyond the crest of which it comes in conjunction with the slates of the Beibur N. Near Phulkot the slates are in abrupt contact with the Nummulitic limestone by a reversed fault. This fault was traced by Hira Lal along the

intervening country between this point and Bugnotur *viâ* Khetur. As this fault crosses the Kula N., the Beibur N., and the intervening spurs, it will be seen that it Vs slightly up the gorges indicating a hade to the south-east of the reversed fault along this part of its course.

Neighbourhood of Beerun Gulee.

We have only now to note the dying-out of the outcrops of the younger formations along this line of section as they trend north-east towards Beerun Gulee, and the hill-spurs which rise north-west and south-east of it. The narrow strip of Spiti shales near Nerrian has already been stated to die out about a mile from that village. The Trias band, among which they lie, continues much further in that direction, but also dies out against the fault about the "B" of Beerun Gulee, although it is continued on the hill-spur just north of the pass at Beerun Gulee, beyond which in the direction of the Silole N., as has already been described, the country descends steeply and is cut out entirely in the heart of the great Slate series. The thin slate band near Batungi, which in the sketch-section (fig. 19) has only just emerged from beneath the Trias, expands on the contrary in a north-easterly direction and joins the great slate area beyond Beerun Gulee. The rest of the section in the Trias, and the briefly extended band of Spiti shales, die out against a prolongation of the fold-fault which starts near the "i" of Batungi, the last fragment of the Trias being just to the south of the "G" of Beerun Gulee.

North-west of Beerun Gulee, and north of the villages Malsuh, Batungi, etc., the hill-spurs begin to rise steeply towards Musta peak, 8,435 feet, and to be covered with the usual north temperate conifers, oaks, etc. At Malsuh several oak trees, forming a small grove, were covered thickly with mistletoe at the time of our visit. Beerun Gulee itself marks the end of the Tandiáni Musta hill-range and the beginning of the side spurs projecting from the Mian-Jani and Oocha-Truppi range.

The continuation of the Bugnotur-Jhootmung outcrop of the Nummulitic limestone, with the underlying Jura-Cretaceous and Trias,

to where they disappear against the Bugnotur-Khetur fault, was filled in on the map from a distant view seen from Mian-Jani, 9,793 feet. A splendid panoramic view over the country just described is obtained from this vantage point, not to mention the still more distant view across into Kashmir and beyond to the great Nanga Parbat snowy peak. My drawing of this panorama was, however, interfered with on the only occasion on which I climbed the hill, by the indisposition of my servant and coolie, both of whom in turn fell down unconscious whilst holding the umbrella over my plane-table. I was obliged to bring them to with bottled beer, the only liquid with us, and then to send them down into the shade of some trees to a patch of snow.

Mian-Jani sections.

The section north of Mian-Jani along the ridge I was unable to examine during the last hot weather spent in Hazara, for the reason given in the introduction, that snow lay in thick and impassable drifts upon certain northern faces of the ridge until the rains set in. Having viewed the ridge from all points of the compass, I am morally certain that the Slate series alone is present the whole way to Puttun. All the lower eastern spurs were examined from the Koonhar river, and they are similarly constituted. Even more so than on the eastern flanks of the Tandiáni ridge, do these spurs and the intervening ravines descend sharply and steeply to lower levels. South-west of Mian-Jani the great gap between it and the Kalabagh ridge is filled with splendid forest of Paludar and Biar, as also are the northern slopes of Moorchpoori in the Nummulitic zone, and the great valley of the Bukot N. Some of the forest trees are here of phenomenal size. The Kalabagh band of Trias limestone, which has already been traced into conjunction with that of Deewal, breaks up into two bands which were traced by Hira Lal across the south-eastern spurs of Mian-Jani as far as its eastern spur, after which they appear to die out. At the deep gap just referred to they are separated from the Nummulitics of the Nummulitic zone by the great fault which divides the Slate zone from the Nummulitic zone.

The Slate zone as a whole.

In taking leave of the descriptive part of the Slate zone, the following more noteworthy results of a general character may be here summarised :—

1. Despite the great expanse of country occupied by the Slate series in this zone, and despite the great vertical range through which they are exposed, there is only one locality away from the border of the crystalline and metamorphic zone, namely, near Puttun, where they possess the slightest trace of a mineralisation along their folia, tending to link them with the crystalline schists.

2. As regards the Infra-Trias, we have found that it is confined to a well-marked sub-zone on the north-western side of the main zone, and that although continuous the whole length of the zone, it dies out with extraordinary rapidity in the opposite direction.

3. Nothing is more noticeable throughout this zone than the persistent mutual inter-relationship existing between the various members of the stratigraphical sequence from Trias to Nummulitic, so that each and all are almost invariably found together in the same cliff section or on the same hill-side.

4. As regards the geotectonic features of the area we must note—

(*a*) The uniform steady strike of the area, north-east and south-west, or thereabouts.

(*b*) The generally elliptical or lenticular shape of the outliers of the formations younger than the slates.

(*c*) That these outliers taper away very gradually as a rule in a south-westerly direction, whilst to the north-east they are rather more abrupt and blunted.

(*d*) That the flexuring of the area is of a rather extreme type, and somewhat more marked and characterised by isoclinal folds along the Infra-Triassic sub-zone than elsewhere, and that the sigmaflexure type of fold with accompanying overthrust is prevalent.

(*e*) That the faults, as would be expected in such an area of great disturbance and flexuring, are generally of the nature of reversed strike, or fold-faults, whereby the outliers of the younger rocks are made to plunge or dip down on one side (generally the north-west) against the older series.

5. One of the most patent facts about this zone is that the sculpturing of the area by denudation has been very intense and long continued, as is testified by the great size of the valleys and plains excavated in this zone, by their irregular course, either with or across the strike or at any other angle to it, by their great depth, and by the fact that no single instance is to be found throughout the zone of uplift areas of what is known as the Uinta type, that is to say flexures that by their original form have given immediate shape and character to the resulting mountains and glens ; in other words, no valley is ever a pure and simple synclinal, and no hill is a pure and simple anticlinal. We may also note, as further exemplifying the great activity displayed by denudation, that most of the ridges steepen towards their crests and are very deeply scored by side ravines.

6. That the topography, resulting from (5), presents the high contrasts of towering crags and culminating peaks overlooking the deep river and stream-beds, and shews a marked tendency to a natural division of its surface into isolated ranges and culminating points with radiating spurs, *e.g.*, Gundgurh range, and the Sirban, Tope, Tandiáni, Taumi, and Mian-jani centres; from each of which its own hill-sides descend in spurs and buttresses and give to it a distinct individuality of its own.

CHAPTER IV.—DESCRIPTIVE GEOLOGY—*contd.*

C.—THE NUMMULITIC ZONE.

Orography.

The boundaries of this zone have been given, page 87. The zone is an exceedingly characteristic one. Throughout its whole extent

on the map it may be seen to be very sharply defined by bounding faults or overthrusts from its two neighbouring zones. Like the Slate zone it takes its name from the rock most prominently displayed at the surface, *viz.*, the Nummulitic limestone, although unlike the Slate zone this is not the lowest formation visible but very nearly the highest. Wherever through erosion, or by reason of the crumpling and faulting of the rocks, the lowermost strata of the zone are exposed, they belong uniformly to the Trias. We have already seen that the Infra-Trias series was unrepresented along the southern sub-zone of the great Slate zone, and therefore we should not expect to find it anywhere visible in this still more southern zone of rocks; and this is found to be the case. But besides this, there is also no visible occurrence of the Slate series beneath the Trias. If we follow up any of the long straight longitudinal valleys, or traverse down any of the deep-cut transverse gorges belonging to this area we shall alike find the Trias limestone to be the apparent base of everything—the geological foundation of this zone; just as the slates, and nothing below them, were found to be the lowest exposed strata in the Slate zone.

One of the most striking orographical features of this zone is the absence of wide alluvial valleys such as the Dore, and also the absence of plains such as the Abbottabad, Hureepoor, and Mansehruh plains. Another very noteworthy feature of this zone is that the main rivers, streams, and valleys are parallel to the general strike of the country (E.N.E.—W.S.W.); and between them run parallel hill-ranges. The valleys are narrow and winding, and sometimes of considerable steepness, whilst the intervening ranges form either continuous masses of the nature of scarped, craggy, narrow but broad-topped table-lands, or, if they are cut through by transverse streams, the latter are of the nature of deeply-cleft gorges, so sharp and precipitous that they are hardly visible until one is directly over them. There are also no isolated hill-masses like those of Sirban, Gundgurh, Tandiáni, etc., in this zone, nor are there disjointed outliers of younger rocks above older with circular or

elliptical outcrops. The bands of the different formations are everywhere much more continuous in straight lines. In other words, the denudation of this zone appears to be in a comparatively backward state, and the face of nature still has its more prominent features determined by the original earth crumplings. It is not easy to gather any idea of this from the map of the country with this memoir, but if the two panorama views (plates 9 and 10) be examined with this object, the difference will be very apparent. Although the general sculpturing of this zone follows largely the strike of the rocks and the axes of the folds, there is nevertheless a great orographical feature with a north and south alignment which must not be overlooked. I refer to the so-called backbone of this part of Hazara, which, connected to the north with the Mian-Jani-ki-choki and Tandiáni masses, extends by means of a number of lofty peaks and intervening gaps (called gulees) as far as Murree. This is the line of watershed between the Jhelum drainage to the east and the Indus drainage to the west; and along it from Tandiáni to Murree we can enumerate the following higher points and intervening "gulees," *viz.*, Tandiáni, 8,845 feet; Beerun Gulee, Oochatruppi, 9,501 feet; Mian-Jani-ki-choki, 9,793 feet; Bukot Gulee, Moorchpoori, 9,232 feet; Doonga Gulee, Kamur, 8,919 feet; Koonja Gulee, Changla Gulee, Chumbi, 8,751 feet; Khaira Gulee, Bumkot, 7,028 feet; Deria Gulee, Kooldana, 7,060 feet; Kooldana cross-roads (gap), Murree ridge, 7,267 feet. A good many of these points can be recognised in the Moorchpoori panorama (Pl. 8), together with the strike-ridges and intervening streams which descend to the Jhelum valley. A view in the other direction is represented in the Changla Gulee panorama, where from the culminating points of Chumbi, Bumkot, etc., we see a series of better preserved strike-ridges and valleys travelling south-west, the perfect parallelism of which may be gathered from the way the perspective makes them regularly converge in the distance.

Although this north-and-south backbone has a unity of its own, inasmuch as it divides the waters which go east from the waters which go west, yet to a geologist, if to no one else, its ultimate

composite character is very clear. Each of the culminating peaks is the decayed remnant of one particular fold or set of folds of the earth's crust—folds which cut nearly at right angles to the watershed. Consequently, if we take any one of these peaks, we find its structural equivalent not to the north and south of it but to the east-north-east west-south-west of it. Thus, to give one instance, the Moorchpoori massif may be readily seen to be a rather high development of the steady uniform range of Nummulitic limestone on which the names Tutreeluh, Bulkot 6,103, Balkooh 5,074, Doobran 4,977, Sribang 5,661, Chujjiyan 4,668, Janomar 4,387, and Serh 4,005, are to be found. Similarly each of the gaps or gulees has its structural equivalent, not in other similar gaps to the north or south, but in the longitudinal valleys running either west-south-west or east-north-east.

So far as European visitors and residents are concerned, the north-and-south watershed from Murree to Kalabagh is the part of this zone which is the best known. Its general elevation from 7,000 to 8,000 feet makes it a very suitable hot-weather resort, and so it is dotted over at intervals with clusters of little wooden houses and barracks for summer residents, troops, schools of musketry, etc. Many tourists and sportsmen on their way to Kashmir make a short stay in the gulees. The luxuriant growth of coniferous trees covering all the main peaks and ridges, and the steep glens in the neighbourhood, is a striking and beautiful feature. There are the stately pillared groves of Paludar, *Abies webbiana*, which strike their roots firmly into the summits of the chief ridges and spurs, and so defy wind, rain and snow, everything in fact except the lightning which has left its blasting mark on the more pointed summits such as Moorchpoori and Chumbi; there are the closely packed hollows among the slopes filled to overflowing with the pale green Biar, *Pinus excelsa*, whilst here and there among these more prominent genera may be found oak, horse-chestnut (decked with blossoms in the spring) the maple or sycamore, and two species of elm, the broad-leafed and the narrow-leafed. All these and some few other less important trees make up forest scenery which would be

remarkable anywhere, but which to the streams of jaded refugees from the hot weather of the plains and the burnt-brown dusty colour of everything, is a memory never to be forgotten.

But whilst the single line of hill-road connecting the gulees with each other is alive during the summer with coolies and baggage mules,—whilst every household, dâk bungalow, and tiny bazaar swells the chorus of recruiting humanity among the echoing woods,—within rifle-range and almost within a stone's-throw down the steep "khuds" to the east are abysses of almost trackless forest, on the outskirts of which the grass-cutter plies his sickle, but the heart of which must be better known to bears than to man. Further down again on favourable ridges and the lower slopes of the mountain-spurs come a few villages with their terraced fields reaching down to the Kanair R, which marks the boundary between this zone and the Upper Tertiary zone. As the winter months approach, residents, troops, civil and military officers, bazaar shopkeepers, and even the post office and telegraph office clerks and the dâk bungalow care-takers, all leave the ridge for the lower country, and the forest-covered gulees are again silent save for the roaring wind and sweeping snow-drifts.

On the western side of the watershed the side ridges lower gradually in height, and the wooded glens steepen as they join up with one or other branch of the Hurroh R. The tall conifers cease about the 6,000 feet level, and forest, with the exception of scrub jungle, almost entirely ceases. The low scrub jungle of Sanatha (Sunhetta), *dodonæa burmanniana*, the thorny Sumbal and Phulahi, *acacia modesta*, Ber, *zizyphus*, etc., with here and there a few of the following trees, Kangar, *pistacia integerrima*, Darwa or Drawa, *cedrela, serrata*, Batangi, wild medlar, Khair, *acacia catechu*, Bis, willow, Tut, wild mulberry, *morus indica*, Dhaman, *grewia oppositifolia*, etc., etc., is of considerable importance as a source of firewood for the Rawalpindi, Hureepoor, and Abbottabad neighbourhood. Hence it is reserved over a great part of the area drained by the Hurroh and its tributaries north and south. Along the longitudinal valleys, and here

and there upon the hills, there are villages, nearly all of small size and often very much scattered and overlapping down the narrow strips of alluvium lining the river-beds. As may be imagined, cultivable land is scarce, water on the porous limestone hills is often a question of moment, and hence it is that these parts are but scantily inhabited, and so much land is given up to the growth of firewood.

Although it cannot be said to be difficult of access along certain lines of road and along the principal valleys (for within a few miles of the pebbly river-bed the gorge of the Hurroh R. is the main highway), yet the crossing of these rugged limestone hills, often steeply scarped and covered with the tough tenacious Sanatha, is sometimes less of a pleasure than a necessity to the geologist, and many weary hours have been spent forcing one's way through the dense undergrowth.

In the extreme western part of this area the Hurroh valley in the neighbourhood of Khanpoor at last opens out into a wide and smiling plain, the strike ridges fall to still lower levels and many die out under the alluvium in the direction of Oosman Khatir.

(1) *Sections in the gulees.*

General.

The Mian-Jani, Bara Gali and Taumi hill-masses, composed of the great slate-formation with prominent bands of quartzite, form the last outcrop of the Slate series in a southerly direction. It is parted from the Nummulitic zone by a great long sinuous fold-fault parallel to the general strike of the country. This has already been defined as the northern boundary of the Nummulitic zone. The presumably lower palæozoic, or older, rocks of the Slate zone, and the great spread of nodular and concretionary limestone of lower tertiary age are brought into direct contact by means of this fault, which must be imagined as of the nature of a great overthrust of the older rocks above the younger. Only in one place—*viz.*, at Bukot Gulee—is there anything left of the intermediate formations in the shape of a band about ½ mile broad of the Trias limestone already mentioned (page 175); whilst nowhere is there an unfaulted boundary embracing a normal or inverted ascend-

ing series through Trias, Jura-Cretaceous and Grey limestone. This is alike true in the section along the steep ridge north of Kalabagh and also in the deep "khuds" on either side of this ridge. The view looking west-south-west from Kalabagh (Pl. 5) will give some idea of the unswerving and important nature of this line of fracture and overthrust. Incidentally we may note in that sketch the barren hill-sides on the scarped southern face of Taumi and the Biar-covered northern slopes of the Nummulitic limestone. Both aspect, and the different nature of the soil due to the rocks beneath, seem to have been efficacious in marking this difference. A similar contrast is observed on each side of the fault as it passes east by the Bukot gulee and along the Bukot stream.

Section along the road from Kalabagh to Doonga Gulee.

Although the line of country indicated in the margin does not cut directly across the strike of the rocks but diagonal to it, it will be convenient to describe the section on account of its accessibility and the exposures afforded by the road-cuttings. The great overthrust to the north of the zone passes ¼ mile or less north of Kalabagh through a sharp gap in the ridge where the road for a moment gives a view down into the Kula N. The Nummulitics which then set in consist of limestone and grey splintery shales of the ordinary kind, but no good exposures are seen until Kalabagh is reached. The strike there is east-north-east—west-south-west and the dip north-north-west at very high angles in massive limestone. In some local sections the strike is east and west and the dip accordingly. A little south-east of Kalabagh the quantity of limestone relatively to the shale becomes less, and in the direction of Nathia Gulee (which is due north of Milach) shales become still more prominent, interbedded with concretionary limestone, and very much split and cross-jointed. Among the shales numerous small *foraminifera*, *ostreæ* and corals may be noticed, but they are minute and extremely ill preserved. The strike continues the same and the dip is approximately vertical. Owing to the preponderance of shales at Nathia Gulee the hill-sides are more flowing and the necessary sites for houses have

been easily obtained. Numerous springs of water issue along the lines of these shales.

Continuing along the road south-east of Nathia Gulee the lime stone increases in importance again. Some few fine exposures of massive limestone give a dip of 80° N.W. and then 60° S.E. and S.S.E. Alternations of limestone and shale are, however, the rule, the former showing lenticular-tabular, concretionary, and massive varieties of dark grey colour, but weathering whitish. Fossils are easily discernible, but of small size. There is also much curving of the strata, with slicken-sided surfaces and infiltration veins of calcite. As regards the peculiar concretionary habit of the rock which I have named lenticular-tabular (and which resembles the structure of the same name in the gneissose-granite), it is but natural to suppose it an imperfectly concretionary one, but there are some few places in which the lenticular structure seems to cut across the bedding more or less. One such locality is on the road ¼ mile south of Nathia Gulee and another 1 mile N.W. of that place. Hence the structure may partly be due to a yielding of the rock along shear planes, the concretions in the limestone being involved in the process in the same way that the crystals of orthoclase in the gneissose-granite have been (see p. 65).

Continuing along the road where it]Vs up the stream from Moorchpoori (now the spring-head of the Murree water-supply) we pass many well-bedded blocks of strata full of fossils and with vertical dip, strike east-west. At Doonga Gulee more shaley beds set in.

Section along the Moorchpoori ridge.

If instead of traversing along the road from Kalabagh to Doonga we take the west-north-west spur of Moorchpoori, keeping to the ridge, we shall find much the same sort of section as far as the thick surface soil and the undergrowth will allow. The ridge rises gradually in rather irregular steps as the strike of the rocks, oblique with regard to the ridge, brings in shales and limestone alternately. From the crest of the ridge as we proceed magnificent peeps over Kashmir may be obtained between the towering stems of the Paludar, wherever nature or art has made a

clearing. In the thick leafy undergrowth through which we pass we may notice the many-coloured balsams, wild strawberries and raspberries covering the slopes, maiden-hair fern nestling among the lime stone crannies, primulas, wild geranium, buttercups, daisies, sorrel, dock, larkspur, and the strange cobra-plant.

Between the west-north-west spur of Moorchpoori and the N.E. spur of the same which goes to Bukot, there are steep slopes and glens full of forest except along the great water and snow slides. The outcrops of the strata cannot be well seen along these slopes, and but an imperfect notion of the rocks can be got by taking the road to Bukot or Kohala from Nathia Gulee which follows below these slopes by the side of the Bukot stream. The great fault takes a line now on one side and now on the other of the stream-bed as far as a point 1½ miles west-south-west of Bukot village, when it turns gradually away towards the north-east, north-north-east and north. Before this happens, however, there are imperfect exposures on the road of the Spiti shales and Gieumal sandstone, outcropping E. and W. and cutting the N.E. ridge from Moorchpoori by some fields at Khun Khoord (according to observations by Hira Lal), after which the outcrops turn south along the eastern face of Moorchpoori. The north-eastern continuation of this zone consists now entirely of Trias limestone following below the Jurassics, and travelling as a narrow tongue from ½ to ¼ mile wide with a north-and-south outcrop as far as the junction of the Jhelum and Koonhar, after which it passes out of the district. This great turn in the strike and direction of the disturbance zone boundaries from east-north-east to due north will be found to be a general feature as the Jhelum valley is approached.

To the south-west of the road from Kalabagh to Doonga Gulee, steep spurs and slopes descend to the stream below Milach, and here we must notice the appearance of ne prominent outlier of the Kuldana beds and of two or three thinn r bands of the same rock on the slopes a little south of Kalabagh. O account of the bright purple colour of the associated gypsiferous shales and clays, these beds may be easily recognised

Section below Milach.

from afar, and during the rains they change the flooded water of the Milach stream (Hurroh R. head-waters) to a reddish chocolate colour. The presence of these outliers of higher tertiary rocks in this valley, whilst there is no trace of them along the strike on the Moorchpoori ridge, is a peculiarity which requires accounting for. The exposure of the rocks in the bed of the stream is rather peculiar. Steep crumbling slopes of them, densely covered with forest on the south side, and bare on the north, lie in an apparent anticlinal—see fig. 21.

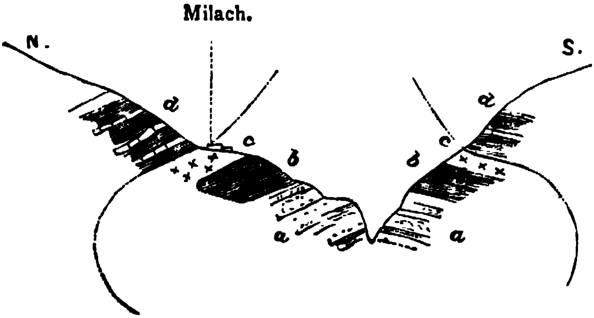

Fig. 21.

The lowest part of the apparent anticlinal is composed of purplish red splintery shales with purple and grey sandstone courses, *a*. Higher up in the section the sandstone dies out and nothing but purplish shales remain, *b*. Above this again in contact with the Nummulitic rocks there is a layer of gypsum and dolomite, the former often filling up the interstices of the latter, *c*. The Nummulitic rocks appear above, first as shales and nodular limestone, *d*. Wynne in one of his papers[1] refers to these red rocks as though he admitted the possibility of their belonging to the Infra-Trias, although he thought it more probable that they belonged to the Kuldana beds. The latter view seems to me to be the only possible interpretation. No difference is observable between them and other sections in the Kuldana series near Murree, whilst the dark sandstones associated with the purple shales are very typical Tertiary sandstones, a rock

[1] Rec. G. S. of I., Vol. VII, pt 2, 1874.

not easy to mistake for anything else.[1] Assuming this, the difficulty is to account for their present position, for if the apparent anticlinal is a real one, then the strata from Nummulitic limestone to Murree beds, including the anticlinal, are upside down, a thing difficult to believe and at the very least very improbable. But if the outlier was originally a remnant of a much-folded synclinal, it might be better understood as a *noyeau synclinal detaché par étranglement* (Heim and Margerie) as indicated by the dotted lines in fig. 21. Possibly, however, much of their present position is due to a surface slipping and sliding *en masse* of the soft shaley material down the hill-sides from an originally much higher level.

I have not attempted by means of a horizontal section or otherwise to indicate the precise nature of the foldings of the rocks in the zone over which we have so far passed. It must be understood that the reason for this is that there are no sections sufficiently clear and free from forest and other surface covering as to warrant such regular treatment. The descriptions of these gulee sections, however, are given with a certain amount of detail, because of their accessibility. A little further south-west in the zone, the rock structure is much more easily deciphered, and has been selected for the line taken by horizontal section No. 3.

Section from Doonga Gulee to Changla Gulee.

Returning to Doonga Gulee and continuing our irregular line of section along the Changla road *viâ* Kamur peak and Koonjee Gulee (the section here follows the bridle-road south-west of the ridge, not the new Murree water-works road) we traverse at first diagonally across the edges of Nummulitic limestone, apparently dipping 60°—70° south-east, which is followed by grey unfossiliferous limestone up to a point north-north-west of Kamur. Here, with vertical dip, comes in a slip of Cretaceous and possibly some Gieumal sandstone and then more Grey limestone with varying dip, but

[1] Dr. Verchère, Journ. As. Soc., Bengal, Vol. XXXVI, 1867, refers to these rocks as Geyserian, and speaks of them as composed of minute acicular crystals of albite, tufaceous limestone, and covered by rubanneous and dark slate much disturbed.

generally inverted to the south-south-west at high angles. A little north-east of the last "a" of Pasala the great band of Nummulitic limestone comes to an end, and at the 16th milestone from Murree we turn a corner of the road shewing Gieumal sandstone with numerous fossils. A little further on, Spiti shales with concretionary layers can be seen; but the proper relations of each to each, though not difficult to understand for one who knows the much better exposed sections elsewhere, is a puzzling bit of stratigraphy, with the solution of which I need not trouble the reader. Trias limestone, as characteristic as possible, and still shewing inversion to the south-east and south at 55°—70° follows; and on turning into the bay of the road due west of Kamur peak we can follow by the eye the Jura-Cretaceous band as it travels away to the west-south-west in the direction of the "n" of Bagan, and cutting as it does so straight across steep rocky hill-spurs and profound ravines, as if a vertical dip was its true position. On the other side of the Kamur hill the Jura-Cretaceous can only be seen dimly exposed on the Murree water-works road, but its position and the general outcrop of the massive Trias limestone can be followed by eye, down into the profound wooded gorges of the Lahor N. and across the southern buttresses of Moorchpoori to join up with the band on the eastern face of that hill as traced by Hira Lal. To actually trace this band foot by foot from the Kamur ridge to Hotur is almost impossible on account of precipices, long grass, and dense forest. Its general lie here, too, is approximately vertical.

The Trias band has a width of about 1 mile, and we may therefore presume some refolding among its strata; but anything like certainty on this point cannot be arrived at from road exposures which are as a rule a mere girdle of clear structure round the forest-covered hill. On the eastern side of the ridge, however, there are some few fine rock exposures laid bare by the engineers of the water-works road.

The southern boundary of the Trias band is a fault bringing in the Nummulitic limestone suddenly, once more, along the line as

shewn on the map, at the 14th milestone from Murree. Near the junction the exposures shew great irregularity of dip, but gradually N.N.W. and S.S.E. dips become the rule in shales and concretionary limestones. About ¼ mile before reaching Koonja Gulee the limestone becomes very nodular and its dip steadies down to 45° S.E. At this place the rock in its excessively nodular character more nearly resembles that of the Salt-Range than before. At the Koonja Gulee bazaar the dip is nearly vertical in shales and limestone, the actual direction wavering on one or other side of the vertical.

From Koonja Gulee on for a mile or so the road follows the ridge as a whole and displays the same kind of rocks in endless alternation or repetition. Notwithstanding the most detailed notes taken on the spot, the nature of this great Nummulitic formation, and more particularly its indivisibility (except broadly) into stages, are such that it is impossible to give any detailed solution of the structural problems presented by it. The strike keeps fairly constant, but as for the dip, the only thing certain about it is its uncertainty, and the complete irrelevance of the local dips for indicating a true dip. Similar difficulties occur all through the gulees, and neither Waagen, Wynne, nor Stoliczka ever attempted more in their sections than to arrange the various formations and beds like an irregular row of books on a shelf. Nor can I claim to have been much more successful, for the most I can say is that the northern half of this Nummulitic outcrop seems to be composed chiefly of the upper beds, whilst to the south of the 11th milestone (where the road passes to the east side of the ridge) there occur outcrops of the massive grey limestone as well. A band of pisolitic rock intervenes and afterwards appears again on the other side of the grey limestone at a point a short distance south of the 10½ milestone. Whilst this rock has a great resemblance to the Sabathu bottom-bed of the Nummulitic formation, it also is, I think, the equivalent of the coal-bearing sandstone of Hewson's. After a short interval of concretionary limestone (60 yards) a third more doubtful appearance of the same pisolitic band brings in grey limestone again, a mere fragment, and then dark

Nummulitic-bearing limestone sets in near the 10½ milestone. Then follow thin-beded limestones, shales, etc., with innumerable badly-preserved fossils up to Changla proper, at the 10¾ milestone, and thence on to the Changla Gulee dâk bungalow.

The whole of this line of section from Doonga Gulee to Changla is heavily wooded, and the watershed is so slender and steeply cut back in places by the side-streams that its instability and irregularity as regards dip is not to be wondered at.

Section from Changla to Khaira Gulee.

We now come to a sub-zone of formations extending in width from Changla Gulee to Khaira Gulee. They shew Nummulitic, Jurassic (southern type) and Triassic rocks, folded, refolded, and faulted, but all lying with a nearly uniform apparent dip to the northward at angles varying from 60° to 90°. Here, as before along this gulee road, there is very little to guide one except the single line of road cuttings, supplemented on the eastern side, however, by the exposures laid bare by the water-works road. Waagen's first paper on Hazara embraced this sub-zone of rocks, and it was here that he first recognised Triassic and Jurassic fossils.[1] To this paper and to that of Wynne[2] the reader may turn with advantage for local details.[3] The following notes are from my own traverse. The complicated nature of the section has prevented its representation on the map being more than diagrammatic. I have refrained from giving a drawn section here as before along this ridge, because I am convinced that faulting and slipping have taken place to such an extent and perhaps so recently that the jumble of formations laid bare along the road would very unfairly represent the proper anatomy of the Chumbi mountain and spurs. If ever an amateur geologist should come to be stationed at Changla or Khaira Gulee, he might spend several months round this lightning-scarred peak in unravelling as complicated a bit of hill geology as heart could wish.

1. Records, Geological Survey of India, Vol. V., Pt. 1, 1872, p. 15.
2. Ditto ditto, Vol. VII, Pt. 2, 1874, p. 71.
3. See also Stoliczka and Blanford, "Scientific results of the Second Yarkand Mission, pp. 9 and 10.

Changla Gulee, from which the section starts, is well known for its school of musketry, and as a half-way halting-place for travellers from Murree to Doonga or Nathia Gulee. Its great height, about 8,000 feet, and the steepness of the south-western face of the hill on which the dâk bungalow is perched like an eyrie, give us on a clear day a panorama over the country through an arc of 180° and extending far beyond the confines of Hazara. The Rawalpindi plateau looks like a great sea or archipelago out of which various strike-ridges, including the Chita pahar, carry on the structural features of Hazara as far as the Indus, whilst beyond that the hills of Kohat, the range of the Safed Kho and the mountains of Afghanistan hover high in the picture like clouds resting on the horizon. I regret that my poor diagram (Pl. 10) gives so bald and inadequate a representation of this wonderful view.

On a suitable day during the south-west monsoon the most marvellous transformation scenes take place. The moisture-laden winds impinging on the base of the ridges burst into churning masses of cloud, coloured most phantastically. Long before Changla feels the blast we may look down from the sunlit bungalow and see the storm-clouds develop in mixed masses of sulphur-yellow, dusky red, and deep indigo colours, the whole writhing with a low hissing sound as they advance.

The action of the atmospheric agencies on the crushed and crumbling rocks of the ridge must be intense; and the steady and rapid movement of soil-cap down hill is remarkably well indicated on slopes of over 40° by the straight stems of the conifers, all of which a yard or more from the ground curve in towards the slope like the bend of a golf club. I examined a large number of examples of this kind on steep slopes, and without knowing whether the matter has been remarked on before, it seems to me to be only explicable by the downward movement of soil-cap acting obliquely against the geotropism of the tree.

Apart from slow soil-cap movement, however, the rocks round about Changla and the whole of the gulee ridge shew abundant

evidence of instability, by landslips in the rains and snow-slides in the spring.

Returning to the section where I left it at Changla Gulee dâk bungalow, the following is the sequence in tabular form as far as Khaira Gulee. All the beds must be imagined as tilted up and dipping at an angle of from 60°—90° N.N.W. The figures after each bed indicate the width of the outcrops as passed along the road itself.

	(1) Nummulitic limestone and shale, much disturbed, with fossils and carbonaceous and ferruginous clay at base	500 ft.
	(Here occurs a spring of water along a slip or fault.)	
	(2) Thin-bedded, splintery, buff-coloured shales and marly limestone	50 "
	(3) Blue-grey, dark, flaggy limestone	50 "
	(4) Limestone, irregularly bedded, with crushed carbonaceous shaley layers	40 "
Jurassic.	(5) Grey limestone crowded with obscure compacted shells, passing into (6)	16 "
	(6) Brown earthy Gieumal sandstone	45 "
	(7) Jet-black Spiti shales	65 "
	(8) Repetition of (6), but darker and more trappoid	50 "
	(Covered ground)	45 "
	(9) Grey-coloured shales (Spiti ?) containing belemnites and ammonites and with rolled black cherty pebbles at base	20
	(10) Well-bedded finely oolitic limestone, Trias	225
	(Here occurs another spring at the 9¼ milestone with a fault.)	
	(11) Nummulitic limestone and shales with coaly layer underlaid by pisolitic earthly ferruginous band	250
	(12) Jurassics repeated as in (2)—(8) and in same order. Bed (9) not visible	200
	(13) Trias limestone as before (10) with fossils, ostrea, etc. (fault or slip ?)	250
	(14) Gieumal sandstone, wall-like mass	70
	(15) Trias limestone with annelid-like markings, strata vertical	400
	(16) Gieumal sandstone	40
	(17) Spiti shales	5

	(18) Trias limestone (repeated by folds ?) . . .	450 ft.
Jurassics in inverted order.	(19) Gieumal sandstone	50 "
	(20) Spiti shales	10 "
	(21) Gieumal sandstone	50 "
	(22) Buff-coloured splintery shales and marly limestone as (2)	50 "
	(23) Nummulitic limestones and shales with ferruginous shale at top, the series becoming vertical at Khaira Gulee. Probably inverted with the Jurassics above	375 "

(Khaira Gulee.)

On the road, now disused, which passes round the eastern face of the Chumbi peak between Changla and Khaira, and also on the water-works road which lies a little below it, I had no difficulty in recognising each of the series as given above, each in its normal position with due regard to the normal strike. The following plan (fig. 22) numbered as in the section above will help the understanding of the surface arrangement of the rocks. It will be seen to differ in its regularity of details from Wynne's map (Rec. G. S. of India, Vol. VII, pt. 2, 1894).

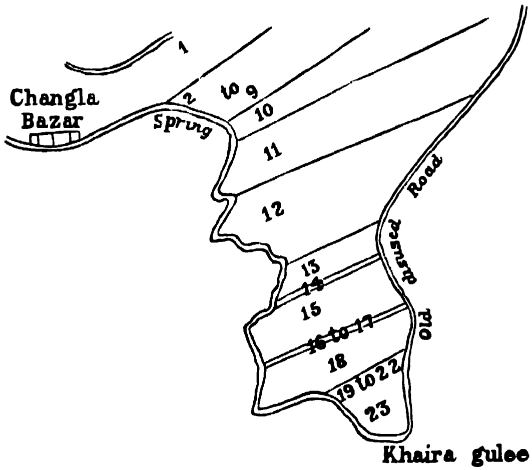

Fig. 22.

Along the eastern road Hira Lal subsequently obtained a large number of belemnites and ammonites from the Jurassics, but their

crushed and broken nature rendered their specific identification almost impossible. Hira Lal was also able to trace the several outcrops in a general way down from the eastern road to the spur going east from Changla towards Malkot.

Continuation of Jura-Triassic band E.N.E.

Crossing this spur obliquely the Jura-Triassic sub-zone was observed to take an E.N.E. direction to Kalaban, whence it runs north and south, in the former direction to join up with the great Trias limestone band forming the eastern base of Moorchpoori, and in the latter to continue for a short way as far as Malkot.

The section west of Kharala and Rumkot was worked out by Edwards in a traverse up the hill-side from the latter place, whence he followed round the junction of Trias and Spiti shales, etc., at the head of the stream west of the "R" of Riyaluh to the spur descending south-west to Kharala.

The section up the Khun spur was traversed by Hira Lal The top of the Trias shewed clearly the unconformable position of the Spiti shales above. Spiti shales and Gieumal sandstone were seen in normal order south-west above Malkot, whilst the village of Khun on the top of the spur was found to be in the Nummulitic rocks.

South-east of the "l" of Malkot the hill spurs which are very steep and débris-covered indicate only imperfectly the way in which the Trias finally ends in this direction.

Eastern and south-eastern boundary of Nummulitic zone here.

From the eastern slopes of the great Moorchpoori mass to the neighbourhood of Malkot and thence to Deria Gulee, the eastern and south-eastern boundary of the Nummulitic zone is a regularly sweeping curve of fault that will be referred to when the upper Tertiary zone is described (see p. 223). Where the Kuldana beds intervene Nature has done the geological mapping of this boundary herself, by means of the brightly coloured red shales of the Upper Tertiaries which follow the upper reaches of the Kaneir (Kanair) N.

Section from Khaira gulee to Deria gulee.

The last of the gulee sections from Khaira to Deria Gulee[1] is entirely over Nummulitic limestone and Kuldana beds. This has been described by Waagen and by Wynne in the papers last quoted. Between Khaira Gulee and Barean Gulee[2] the Nummulitic limestone, nodular and concretionary-tabular, and full of fossils, dips at first north-west, and after ¾ mile the dip changes over to the south-east, at which it practically rests the whole way to Barean Gulee. At the latter place grey shales appear.

The red zone of Kuldana beds south-east of Barean Gulee is well marked, and its continuation north-east can be followed by the eye across the ravine to the spur east of Khaira Gulee.

Nummulitic limestone with varied dip, generally in towards the hill, continues the rest of the way to Deria Gulee.

The gulee section as a whole.

The whole section along the gulee watershed over which we have now gone is singularly illustrative, even in its defects and uncertainties, of the ordinary structure of a typical Himalayan mountain zone taken along one line of country. Regarded apart from everything else, it might stand as a life-long puzzle to the bewildered geologist, and the latter might be excused if he were tempted to regard the strata as having been dexterously shuffled into one another like a pack of cards and then laid edgewise. It is only by a comparative study of other parallel sections such as those now to be described to the west that a glimpse of how this shuffling was effected can be obtained.

(2) *Sections explanatory of horizontal section No. 3 from near Sujkot to Dhar.*

Section from Sujkot to the Hurroh R.

This line of section follows that of the old road from Abbottabad to Murree. At Deewal, and along the little elevated alluvial basin between it and Sujkot the

[1] Deria Gulee is due west of the "K" of Khani Tak.

[2] Barean Gulee is N.E. of the word Dhara on the ridge.

Slate series lies next the limestones and shales of the Nummulitic zone, just as we found it to do at Kalabagh, whilst the inferential boundary fault between the two partakes also of the nature of a great dislocation, though its plane here would appear to be either vertical or with hade to the downthrow. The line of the fault is not marked by any great and sudden change in the configuration of the country. Indeed the change comes on one almost unawares as we pass from the thin-bedded sometimes grey slates to the thin-bedded shales of the Nummulitics. I need scarcely say that the change really is enormous, as is evident at once when fresh unweathered fragments of each formation are taken for examination, but superficially there is just sufficient resemblance to make one recall the observations of other geologists further west who have found the Nummulitics passing into a metamorphic rock in the neighbourhood of igneous intrusions. In case, however, I have raised a spectre of doubt in the reader's mind, let him but remember the included blocks of the Slate series in the Infra-Trias conglomerate of Sirban, and go on in confidence.

A little before reaching Sujkot the change into the Eocene strata full of fossils is well effected, and as we trample the Nummulitic hosts under foot we mentally remark that as road metal, on a particularly ill-kept road, nothing could be worse. Roads in Hazara, it may be remarked, are either good or bad, the former are part of the system of frontier strategy, the latter are *pro bono publico.* Ridge and hollow of limestone and shale respectively strike like parallel wave crests from Sujkot towards Naruh. Further along the road as it follows the winding and ever-steepening defile, carved as if along fissures through the rock, the precipices shew the varied contortion represented in Hor. section No. 3. All the time, in spite of the general tendency to dip to the S.S.E., we are descending in the series. The defile becomes steeper, and the stream makes a fall over an inverted limb of a rock-fold. It next joins the Samoondar N. from Kalabagh, and with added volume and more precipitous sides it now cuts straight across the strike of the harder and more massive

Nummulitic limestone. The road takes us under the Bulkot (6,103 feet) crags, of which we can see nothing owing to their steep angle; but opposite us their exact counterpart is laid bare on the Kagian side of the ravine in a wonderfully fine section. The strata of the north face of the summit of that hill are dipping normally, but lower down the dip steepens to the vertical and then becomes inverted in a long, straight, steady inversion down into the ravine as far as we can look. In horizontal section No. 3 this structure is seen forming the mass of Bulkot summit.

Due west of Kagian we pass a bed of brownish pisolitic iron ore (the equivalent of the coal-bearing sandstone) 6 feet thick; and beyond this grey unfossiliferous limestone.

West-south-west of Kagian dark-brown sandstones (Gieumal) are seen in a bad exposure followed by Spiti shales lying inconformably on an undulating Trias platform. Over on the opposite rock face Kagian village lies on the Spiti shales, and the latter are wrapped up in some fine contortions of the Trias platform represented in horizontal section No. 3 at the point marked *a*.

The road section is now undefined and uncertain, but a sharply cut-back ravine on the south-east face of Bulkot gives us the key to the rest of the section down to the Hurroh R. This is represented in the horizontal section by the varied folds south of the letter *a*. Every detail of this pretty bit of folding is made plain.

The sequence below the "k" of Dukun is as follows:—

Grey limestone	200—300 feet.
Cretaceous (highly fossiliferous) . . .	8 inches.
Ditto (less fossiliferous)	4 feet.
Gieumal sandstone	20—30 "
Trias limestone (base unexposed).	

We have now reached the "longitudinal" valley of the Hurroh, carrying a small stream (in the dry season) easily crossed on foot.

It is hardly necessary to draw attention to the fact that in traversing the Bulkot mass we have passed through the heart of a section equivalent to that from Kalabagh to Koonja Gulee; and it will be readily understood from the way the dip varies as the core of the ridge is approached how risky would have been the construction of a section out of the surface indications supplied by the gulee ridge exposures.

Parallel sections in the same ridge.

In a north-easterly direction the Trias and Jura-Cretaceous beds exposed in the above section continue along the bed of the Hurroh and eventually join up with the same beds observed descending from the western slopes of Kamur. No good exposures there were visited by us. To the south-west, however, the northern side of the Hurroh valley is rich in numbers of beautiful exposures, the Cretaceous band being particularly finely represented. The Trias platform sometimes projects a long way out from the hill-side as represented below fig. 23, and having a moderate dip at the surface, the outcrops V up the stream-beds and sometimes as near Dukkun and Gouruh display complex folding towards the heart of the ridge.

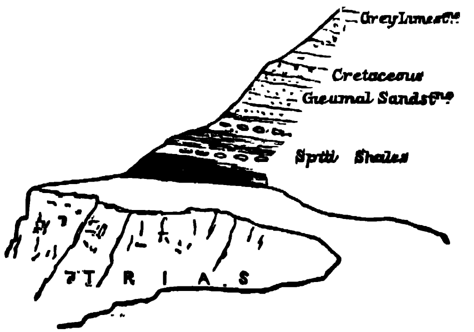

Fig. No. 23.

Beyond Suttoruh under the crags of Balkooh the lie has changed and the Trias and Jura-Cretaceous are inverted at the surface so that they climb up the hill-spurs instead of the ravines.

Particularly beautiful is the aspect of the Cretaceous band, with its black fossils standing out in relief on the pale orange coloured lime-

stone roughly depicted, fig. 24. Both it and the Jurassics can be followed mile after mile along the hill-sides in a perfectly continuous exposure.[1]

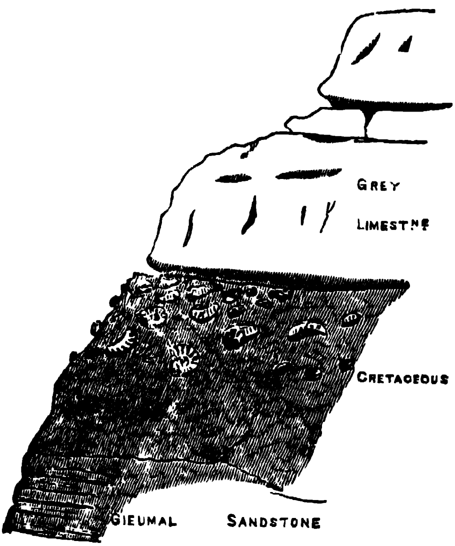

Fig. 24.

As regards the Nummulitics of the ridge, sections south-east of Naruh show numbers of parallel scarps and little valleys, the former being uncultivated bare rough limestone, and the latter excavated along the shaley layers and furnishing a scanty soil for cultivation. These undulating waves of hard and soft rock give way at the crest of the ridge to a steep rough descent over tumbled blocks of limestone down to the Jura-Cretaceous horizon. At Naruh, on the northern side of the Nummulitic zone, there is a certain amount of grey limestone exposed, but generally along the boundary fault between the Nummulitic and Slate zones the opposition of uppermost Nummulitics against slates is as complete an indication of the magnitude of the dislocation as could be wished.

South-west of Suttoruh the sections across the ridge become complicated by the Trias dividing into two bands with a long inlier of Jura-Cretaceous and Nummulitic limestone wedged in between them. The section north-west and south-east of Chinjah shews this in ill-exposed forest-covered hill-sides. A better section is given from near Jubriyan *viâ* Lussun to the main ridge south-west of Balkooh; but even here the working out of the structure of the higher parts is rendered difficult by the dense small forest.

[1] It has always been a puzzle to me why on Wynne's map the Jura-Cretaceous band along this line of country is omitted.

Fig. 25 below gives the structure along this line.

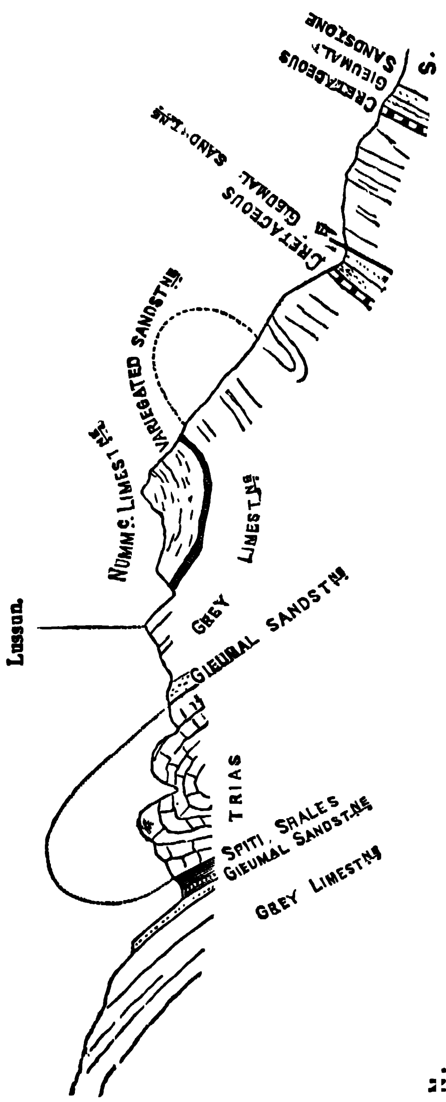

Fig. 25.

With regard to it, the chief point of interest is the exposure of Cretaceous rocks at Jubriyan, from which the better part of the collection of Cretaceous fossils was made by Hira Lal and myself. The rock is abundantly exposed in the low hills to the north of the village, and its more disintegrated state at one point enabled us to secure some fair specimens. The northern of the two bands of Trias, shewn as a lying anticlinal in the sketch section, dies out a little further to the west-south-west. As regards the southern band it is difficult to say what becomes of it under the dense forest-covered slopes of Doobran, but it seems also to die out there in some way. The Trias band below Jubriyan is a third band beginning at Jubriyan. It will be mentioned again later.

For the present we have gone as far aside from our main line of section represented in horizontal section No. 3 as it is prudent to do, and we must now return to it where we left at the ascent of the hill-side to Maree.[1]

[1] This place must not be confounded with Murree, although both names in the Hunterian system would be written Mari.

Section across the Maree ridge to Nugree.

Beginning in the river-bed we may note the presence of high river-gravel cliffs forming plateaux and bracket-like terraces, stuck on to the great and steep convex slopes which descend to the river. Their average height above the river-bed is here about 500 feet.

The hill-side up to Maree is an exceedingly steep climb up a zigzag, which here and there shews signs of having once been a bridle-road. It is broken into fine crags and ledges and is generally forest-covered.

Nummulitic limestone is first met with after leaving the pebbly bed of the Hurroh, so a fault is indicated along the valley, a direct continuation of that south of Kamur in the gulee sections. Up to Maree we then ascend an inverted but badly exposed section to the Trias, which latter forms a thin band near Maree bungalow. This thin band cut off by a fault to the south dies out in a north-easterly direction, presumably near Noushuhruh (its dying out was not traced by us) since it makes no appearance in the gulee sections. In the other direction it becomes thinner and less noticeable, as shewn by sections further south-west, until it also dies out, leaving the Jurassic band to carry on the same line of flexure down the lower parts of the valley of the Hurroh.

As regards the beds between the Trias and Nummulitic below Maree, it is a remarkable fact, already alluded to when describing the stratigraphical elements, that no trace of the Cretaceous band was found. Gieumal sandstone and Spiti shales with the belemnite bed are present, but poorly displayed in broken outcrops.

Beyond Maree, Nummulitic limestone extends to the top of the main ridge, and we then descend the other side towards Nugree for some way in the same. Horizontal section No. 3 will shew the order of succession down this slope. Nothing need be remarked about the Trias limestone, but the northern of the two exposures of Jurassics are detailed below. It will be seen to be in many ways similar to

that exposed along the continuation of the same outcrop south of Changla Gulee :--

(1) Nummulitic limestone.

(2) Sandstone variegated with pisolitic-iron bed.

(3) Thin-bedded grey limestone (small fault)·

(4) Thin-bedded buff-coloured marley limestone, nodular limestone, grey and drab, full of compacted shells (passage-beds).

(5) Spiti shales and Gieumal sandstone in several alternations and inter-beddings.

(6) Trias limestone.

As Nugree is reached, a fault, dying out to the north-east and becoming more marked to the south-west, parts the last outcrop of the Trias from the great expanse of Nummulitic strata with enfolded lines of Kuldana beds which next sets in.

Parallel sections north-east and south-west along the Maree ridge.

Want of space must make me condense the account of the parallel sections found in a north-east and south-west direction. Fig. 26, below, gives a section from the 6,545 feet hill through Hothla to the stream-bed below Seer.

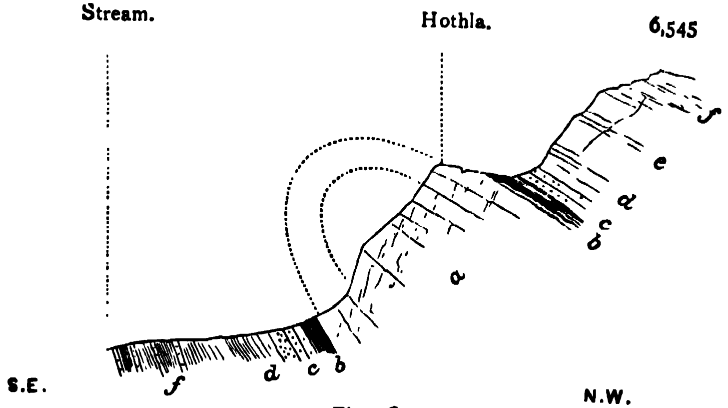

Fig. 26.

a — Trias limestone.
b — Spiti shales.
c — Gieumal sandstone.
d — Thin-bedded buff-coloured calcareous shales.
e — Grey limestone.
f — Nummulitic limestone and shales.

Beyond that up the little valley near Bhatnara in a *cul de sac* with the steep ascent to Changla above, the Jurassics (south-eastern band) splay out over the hill-side shewing great quantities of Gieumal sandstone for a while, until the glen closes in still more, and the south-east band of the Jurassics vanishes under a covering of Nummulitics, as drawn Fig. 27, and the section coincides with the Changla section.

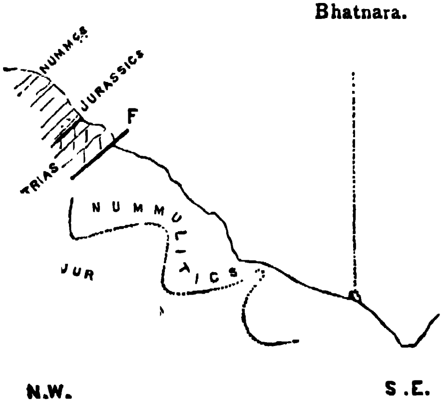

Fig. 27.

Towards the south-west the doubled Jura-Triassic bands continue in regular order from near Nugree for about 6 miles. The section through them as seen south-east of the ridge above Chinali from north-west to south-east is as follows :—

(1) Nummulitic limestone.

(2) Variegated sandstone with pisolitic-iron ore.

(3) Grey limestone, 100—150 feet, passing into

(4) Thin-bedded buff-coloured shaley limestone with chrome-coloured bands.

(5) Thin-bedded ochre and grey concretionary limestones with compacted shelly layers, passing into and interbedding with

(6) Gieumal sandstone, 60 feet.

(7) Grey shales with Belemnites (sudden change).

(8) Trias limestone, 300 feet (fault).

(9) Repetition of (5) and (6).

(10) Jet-black Spiti shales with iron-stained bottom-bed, 40—60 feet (uneven surface).

(11) Trias repeated as (8).

The appearance of the section along the hill-spurs to the east is as shewn Fig. 28 drawn in perspective from north-west of Chinali village. The apparent dip must not be confounded with the true dip, which is nearly vertical, but waving.

Fig. 28.

a = Trias limestone.
b = Gieumal sandstone, etc.
c = Ochre-coloured thin-bedded limes ones with layers of compacted shells.
d = Grey limestone.
e = Variegated sandstone and pisolitic iron ore
f = Nummulitic limestone.

A very similar section is found along the path from Loruh to Trimun; but south-west of this a change takes place; the southern Trias band continues intact to Hullee and beyond, but the northern band vanishes under undulating folds of the Jurassics which, over a large area near Maira and south of Rahee, are badly exposed in rough and complicated country.

Uniformly in all these parallel sections illustrative of the structure of the long hill-range above Nugree, there is a complete absence of the Cretaceous band. All endeavours to fix it among some one or other of the chrome-coloured bands failed, for not a single characteristic fossil, so profuse on the other side of the Hurroh R., was detected. On the other hand, the incoming of a calcareous element among the Gieumal sandstone, and the development of a zone of compacted shelly limestones and buff-coloured thin-bedded shaley limestones further shew that

important changes in this southern band of the Jurassics have been effected.

Section from Nugree to near Dhar.

Returning once more to the main line of horizontal section No. 3, we find the great Nummulitic formation extending the rest of the way from Nugree to Dhar, and only broken by two thin bands of the Kuldana beds. The main line of section crosses the south-west spur of Bhumkot, 7,028 feet, at Liran, but behind it I have introduced the more comprehensive section as it crosses Bhumkot itself. Viewed from near Loruh with the early morning light playing on Bhumkot's rugged and bare slopes, the anatomy of the hill comes out very distinctly. The details in the horizontal section are introduced from a drawing made under those circumstances which, considering the distance of the point of view, may be taken as practically free from errors of perspective.

A peculiar feature in the section is the two more or less broken bands of Kuldana rocks which run like red streaks over hill and hollow. In some cases the amount of gypsum associated with them is considerable. On the "S." of Seer in the Nugree valley the gypsum is about 100 feet thick, the apparent dip of the bands being 60° N.W. The section was—

(1) Nummulitic limestone.		
(2) Banded grey and white gypsum	40	feet.
(3) Gypsum and little red clay	20	"
(4) Repetition of (2) and (1).		

In other localities, as south-west of Loruh, purplish and green shales with banded white and grey gypsum and calcite veins, and sometimes with hard compact quartzose beds, make up the band. About the "D" of Dheree Keyaluh in the stream-bed close to the gypsum of the above band, a spring issues from the Nummulitic limestone giving off sulphuretted hydrogen and depositing sulphur among the weeds in the stream-bed. The limestone in the vicinity, and also the bands of gypsum and clay, are much twisted. Lenticular patches of limestone are sometimes veined with gypsum.

Again on the "m" of Kurum a section 80 feet thick in these beds shews alternations of dark reddish-purple shales, or hardened clays, and fine sandy purple conglomerates.

Jura-Triassic wedge south of Seer.

A little behind the line of section and south of Seer there is a faulted-in narrow wedge of Jura-Triassic rocks, which crosses obliquely the two lower bifurcations of the ridge-spur descending from Changla Gulee, and expands towards the higher slopes of Chumbi into the complicated section between Changla and Khaira described before (p. 192).

River-gravels near Nugree and Loruh.

The only other interruption to the monotonous Nummulitic limestone spurs and ridges in the section is that of the gravel terraces. Their last appearance up-stream is near Nugree. Between Loruh and Nugree the pathway follows the Hurroh river-bed, and we pass continually under the almost vertically-cut cliffs, 200—300 feet high, of compacted gravels or rolled boulders, chiefly of limestone.

The section as a whole.

Viewed comprehensively, the line along which our present section has gone, and the parallel sections introduced in expansion of the same, are such as possess the great redeeming feature of being easily understood in their main structural components. Running as they do across strike ridges and ravines, which mount up to or tap the gulee watershed, they offer keys for the easy solution of the perplexing questions of structure and arrangement found along that watershed.

(3) *Sections explanatory of horizontal section No. 4, from Jub to Sydpoor.*

Generalities.

The great regularity of feature and structure possessed by the Nummulitic zone enables one to pass at once from horizontal section No. 3 to horizontal section No. 4, which lies almost at the other end of the zone. In describing No. 4, the same method will be observed as before of comparing different parts of the section with parallel sections, thus linking it up with No. 3.

The section noted in the margin corresponds to that portion of No. 3 from Sujkot to the Hurroh R. Like it, also, the line of country follows a transverse gorge cut through the Nummulitic limestone for the greater part of the way. Near Jub, the northern boundary fault of the zone divides it sharply as usual from the slates and accompanying limestone bands of the Lunguryal type. The Nummulitic limestones are at first of the nodular or concretionary kind and associated with shales. They are folded in a number of small flexures, and carry with them a disjointed band of the Kuldana red beds.

Section from Jub to the Hurroh R.

Below Riala village, the previously open valley closes in between precipitous walls, and the water of the stream drops over smooth surfaces of limestone in a series of falls: a journey up or down which is beyond the compass of ordinary booted mortals. The falls are situated along the north-north-west reach of the stream across the line of the ridge from the "P" of Kohala Paeen. (The horizontal section just here crosses that ridge.) Below this, the stream vanishes down fissures in the limestone, and the rest of the way to the Hurroh is along a dry boulder-strewn bed, bereft of its torrent, with a width of only a few yards, and with walls of rock rising at angles of 70°–80° from it. This gloomy chasm is only visited by the sun's rays occasionally, and one may wander down it in complete ignorance of one's whereabouts, for long periods together. The natives say it reminds them of Afghanistan. Through the lower part of this gorge there is represented a type of the Nummulitic limestone, which has hitherto been wanting. The beds become of a dark grey and are slightly sandy in places. They are well-bedded and dip the whole way north-north-west at extremely steep angles 70°—80°. In spite of this steepness of the angle of dip along the dry torrent-bed, it is plain from occasional glimpses obtained of the hills above, that the beds spread out above and lie at a lower angle. The horizontal section illustrates this.

As we near Jiroo on the Hurroh river, well-bedded typical Trias limestone comes in beneath the Nummulitics, but the Jura-Cretaceous

rocks are hidden by an obscurity. They are inserted in the section from evidence close by.

Parallel sections to the north-east.

Nature has provided two parallel and similar lines of section to the one just described. The first of these is a transverse gorge passing between the Chujjian and Sribang hills, and the second a transverse gorge passing between the Sribang and the Doobran hills. That to the north-east of Doobran has already been mentioned. The intervening hills are great heavily-built masses, so evidently but parts of one uniform ridge trending towards Balkooh and Bulkot, that the dividing gorges may easily be overlooked. This ridge rises from the Hurroh river to about 3,000 feet above it, in great convex slopes steepening downwards.

The first of these transverse gorges begins near Chujjiyan village or Chothai, and is a scarcely noticeable stream at first, draining a flat cultivated open valley in the upper Nummulitic shales and concretionary limestones. But about half a mile below Chothai it suddenly leaps over a nearly vertically dipping slab of limestone in a fall of about 150 feet. The section then proceeds down a gorge or chasm almost as shut-in as that of Riala. From Chothai village the section is as follows:—

(1) Nummulitic limestones and shales.	
(2) Grey limestone, well-bedded	100 feet.
(Waterfall.)	
(3) Dark-grey sandy limestone	50 „
(4) Dark and pale grey limestone, sometimes rather sandy	350—400 „
(5) Dark-grey sandy limestone as (3) . . .	50 „
(6) Dark and pale limestone as (4) . . .	200 „
(7) Cretaceous.	
(8) Jurassic.	
(9) Triassic.	
(10) Repetition of (3) and (4).	

In the above section, somewhere about the junction between (4) and (5), fragments of the Jura-Cretaceous rocks were found, so there

is probably a fault near that line repeating the section to the south. The apparent dip is north-north-west all through the gorge, being nearly vertical along the stream-bed, and 40°—50° on the Sribang ridge above. The beds curve downwards therefore in a fine arc.

The section down the next gorge from near Lunguryal to Pina, on the Hurroh, is a more perfect one, and it displays the repetition of the sequence better. It is—

(1) Uppermost Nummulitic concretionary limestone and shales, and a few marls full of fossils.

(2) Dark and light grey limestone interbedded with dark sandy limestone, slightly concretionary in upper part, well bedded in lower part. Fossiliferous.

(3) Cretaceous	4 feet.
(4) Gieumal sandstone	20 ,,
(5) Trias	100 ,,

(Fault.)

(6) Repetition of (2).
(7) Repetition of (3) and (4).

(Fault.)

(8) Repetition of (2).
(9) Repetition of (4).
(10) Repetition of (5).

The whole of the beds, with the exception of 8, are dipping as in the last section. No. 8 shows a rolling dip.

I need not stay to describe the intervening sections up the hill-slopes, which possess the same general arrangement of the beds, but with less clearness, and with surface irregularities.

In a south-westerly direction from the figured section No. 4, the Janomar hill, 4,387 feet, carries on the structure of the hill-range. The comparatively wide valley which runs between it and the Serh hill, 4,005 feet, north of Khanpoor, shews the free edges of the beds in that direction. As a summary of various traverses across it and

round its base I give below in fig. 29 a rough profile outline of the hill as seen from Serh and a section across the summit in fig. 30.

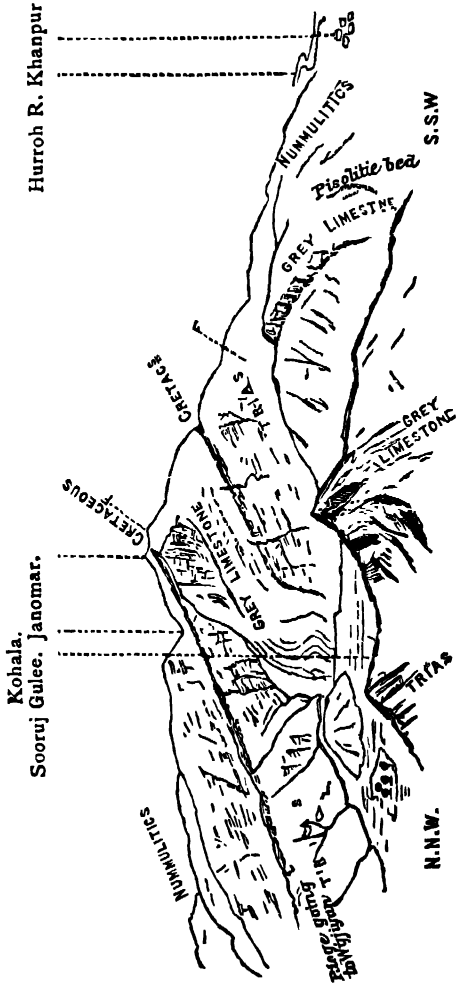

Fig. 29.

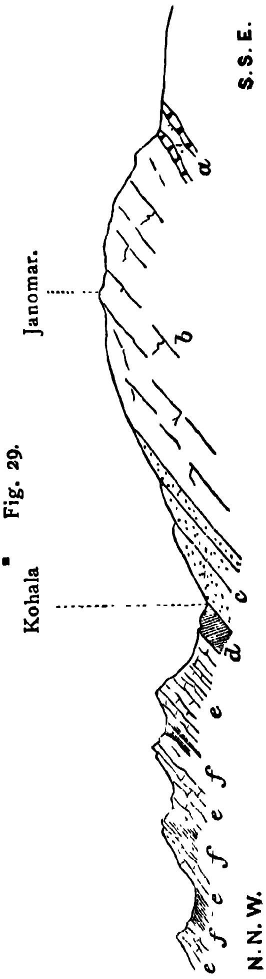

Fig. 30.

f. Pale ochre shales and marls.
e. Pale-grey concretionary Nummulitic limestone.
d. Pisolitic iron-ore . . . . 4 feet.
c. Sandy limestone weathering dark . . . . } 150→200
b. Dark and light grey limestone sometimes pinkish and with nests of calcite . . . . . . }
a. Brownish and yellow sandy limestone with cretaceous fossils, in two or three thin beds.

In the above section the complete absence of Spiti shales, and the shadowy representation of the Gieumal sandstone, are peculiarities which render the tracing of them, and of the boundary between the Trias and Grey limestone, a difficult matter.

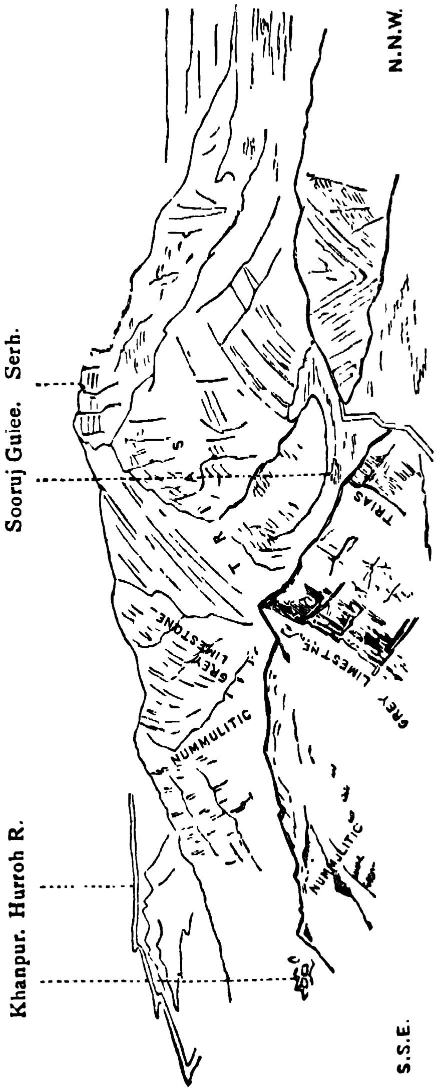

Fig. 31.

The Serh hill has little of interest attaching to it. The junction in this case between the Trias and Nummulitics appears to be a fault, but that face of the hill is so covered with brushwood and thorny jungle that the absence of the Jura-Cretaceous could not be determined every where. Fig. 31 gives a view of this hill from the summit of Janomar.

Both the Serh and Janomar hills absorb all the rain which falls on to them, and they are now completely destitute of streams or torrents flowing down the deserted channels.

Section from the Hurroh river across the Shah Kabul hill to the Nalan river.

Returning now to the main line of horizontal section No. 4, on the southern side of the Hurroh river, we find it takes us over the summit of the double-peaked Shah Kabul hill, 4,440 feet. This part of the section corresponds to that across the Maree ridge, and, as was the case there, the Cretaceous band is absent, and the Jurassics have the limestone beds developed in their upper layers. The section and map together will sufficiently illustrate the structure of the hill, and it only remains to mention that the peculiar dying out of the Trias bands to the west-south-west is due to the rather sudden extinction of the folded anticlinals in that direction, which sink beneath the Khanpoor plain. Between Dhartyan and the northern spurs of Shah Kabul, the Jurassics give the following section in inverted order:—

(4)	Grey and buff-coloured limestone, thin-bedded .	60 feet.
(5)	Ochre and grey compacted shelly nodular limestone in sandy matrix	10 „
(6)	Brown and reddish Gieumal sandstone . . .	80 „
(7)	Trias limestone.	

In the above the absence of any of the Spiti shales is noticeable.

Along the Hurroh river-bed another thin line of Jurassics is of some interest, as in it, near Pina, Hira Lal pointed out to me an exposure of coal in a ferruginous band beneath the Nummulitics. In this section also the Grey limestone beneath the coal passes down into the thin-bedded buff-coloured limestones, equivalents of No. 4 in the section above.

Parallel sections to the north-east.

To the north-east of Shah Kabul hill the three bands of Trias become two, and then proceed regularly towards the neighbourhood of Hullee, where it will now be necessary to give a section. Fig. 32 below is drawn through the hill-mass from near the Hurroh R. to Hullee. In it all the beds are

observed to be inverted at the surface. The Jurassics have a fairly good development, and the following typical vertical section through them may be deduced :—

(1) Nummulitic limestone.
(2) Ferruginous bands—pisolitic iron-ore 1 foot.
(3) Buff-coloured thin-bedded, shaley limestones . . . . . 100 feet.
(4) Compacted shelly limestone . . 50 „
(passing into)
(5) Interbeddings of (3) and Gieumal sandstone . . . . 60 „
(6) Gieumal sandstone with two or three thin calcareous layers of *Trigoniæ* 80 „
Black shaley sandstone and black shales—Spiti shales . . . 5-15 „
Trias limestone, exposed for . . 300 „

Fig. 32.
a = Trias.
b = Jurassics { 1 Thin-bedded buff shaley limestone. 2 Compacted shelly limestone.
b = Jurassics—*contd.* { 3 Gieumal sandstone. 4 Spiti shales.
c = Nummulitic limestone and shales with pisolitic iron-ore x.

Section from near Bukka to Sydpoor.

Horizontal section No. 4, to which we now return, skips the short stretch of country between the Nalan and Bukka village. This line, through a failure of arrangements, was not actually crossed by any of my party. A similar line further to the north-east was, however, crossed near Bhagpoor Dheree and Nurotur. South-east of Bukka, across the rather flat valley in which Talhar lies, and over the final ridge to Sydpoor, the hill structure, though a little complicated, can be understood by reference to the section. The undulating folds of the Jubbi-Gerani ridge, and the sharply refolded strata on the hill-spur near Sydpoor, are particularly well seen. This brings us to the south-eastern edge of the Nummulitic zone which here overlooks the Rawalpindi plateau.

We have now but to note a few parallel sections illustrating the unity of the last part of the section with that described south-east of Nugree and its extension west-south-west to the Margalla pass.

Section between Hullee and Cheran.

Between Hullee and Cheran peak to the south, a rough little watershed runs, parting streams in two directions which reach the Hurroh at different points. The path leads by Choora and Sangrari. This line of country shewed that it exactly corresponds to the part of the zone near Loruh and to that between Khaira Gulee and Kuldana. Nummulitic limestone of most characteristic aspect, together with shales, cover the whole area with the exception of the little gulee between the two longitudinal flat valleys on each side of Sari Syadan. At these places bands of the Kuldana rocks pass, the former joining up in a broken chain with the Loruh band, and extending in the opposite direction at least as far as Bhagpoor Dheree, the latter having no visible continuation for a great distance.

At Mukhniyal also a band of Jurassics starts and connects up with that in horizontal section No. 4, near Talhar.

Over all these Nummulitic hills the Chir pine is conspicuous along the ridges, and two kinds of oak are found in the sheltered hollows. Khair, various figs, Kao, Kangar, Phullai, etc., are also to be found; but the usual undergrowth of Sumbal, Sunhatta, Kokhri, etc., is not so very marked just here, although the south side of the long ridge on which Cheran is placed is a dense and tangled mass of those shrubs.

Sections north-east and south-west of Sydpoor.

The last-mentioned long ridge is here the most southern of the hill ranges of Hazara, and its long unbroken and regular crest and jungle-covered slopes, rise straightly and suddenly from the comparatively level Rawalpindi plateau. The Jurassics which shew in the sharply contorted side-spur near Sydpoor continue to the north-east for some 9 miles, shewing themselves at the foot of the thorny hill-spurs and being traceable by their brown colour and Trigoinæ bed up into the intervening water-courses. At Shah Darah they vanish by the extinction of the folds.

A little east-north-east of Shah-ki-Noorpoor a still more southern parallel range of Nummulitic limestone gradually rises from the plateau, and after extending for some 9 or 10 miles, dies out again. Between it and the greater ridge behind it a narrow band of the Kuldanas starts near Shah-ki-Noorpoor, expands at Shah Darah for a short way, and then becomes of the usual disjointed nature as it keeps its regular line to join up with the typical Kuldana beds of Clifden and Kuldana cross-roads.

To the south-west of Sydpoor the next four or five side ravines all shew exposures of the Jurassics in much the same sort of complicated position as at Sydpoor, whilst beyond that the Jurassics continue as a narrow band to Sha-ala-Ditta to the Margalla pass (just outside Hazara) and doubtless beyond.

At Sha-ala-Ditta the following section is well exposed :—

(1) Nummulitic limestone.	
(2) Iron-stone, brown and red	5 feet.
(3) Bands of chrome-coloured limestone with compacted shells and interbedded with calcareous sandstones containing Trigoniæ	30 "
(4) Gieumal sandstone	10 "
(5) Pale grey limestone	5 "
(6) Chrome-coloured limestone with thin beds of grey limestone, and with two compacted shelly layers .	50 "
(7) Dark purple-grey limestone blotched with ochre patches	20 "
(Fault.)	
(8) Murree sandstones.	

At the Margalla pass where the grand trunk road passes towards Attock, and where the railway tunnels through the low divide, the Trigoniæ beds are well seen, but the sequence of the individual stages is not so well seen as at Sha-ala-Ditta.

Fig. 33 below shews the peculiar contortion of the strata at the pass.

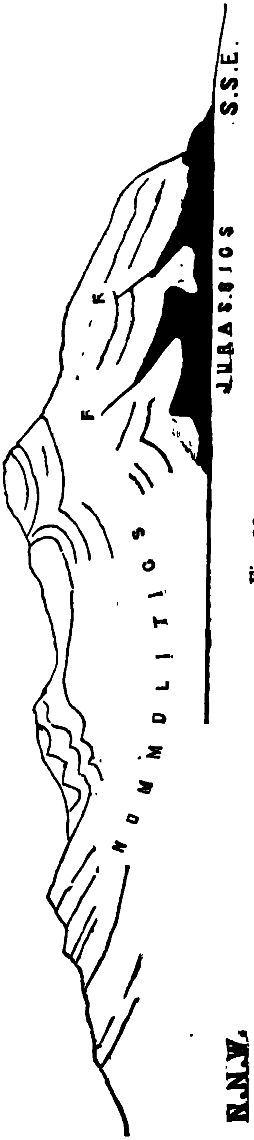

Fig. 33.

The continuation of the Mukhinyal and Talhar band of Jurassics is seen near Khoorum at the south-west extremity of the map. The section there is—

(1) Grey slightly concretionary Nummulitic limestone.

(2) Thin-bedded shaley grey limestone . 50 feet.

(3) Dark rusty-yellow sandy limestone with a few imperfect shells . . . 15 „

(4) Pale and dark chrome well-bedded sandy limestones full of fossils, chiefly Trigoniæ . . . . 30 „

(5) Gieumal sandstone . . . . 5 „
(ground covered by débris).

(6) Ochre and rusty-brown also grey dappled with chrome-coloured limestones with lines of comminuted shells . . 100 „

The beds No. (6) in this section and likewise No. 7 in the section at Sha-ala-Ditta may either be Jurassic, or, as is not improbable, Triassic. In the latter case the complete absence of Spiti shales and all trace of unconformability may suggest a passage here between Trias and Jurassic.

Wynne in his map inserts a band of Jura-Triassic rocks to the south of the little gap on the word Turmukki. I was unable to find any sign of this, only a trace of Kuldana rocks there and a small outcrop of Jurassics east of Toong, 3,629 feet.

Near Khoorum and Shah-ki-Dheri the level of the country has sunk to very insignificant heights, and the parallel gentle folds of the Nummulitic limestone have become smaller and more and more insignificant as the Margalla pass is reached.

At that place there is but one single scarp for the trunk road to surmount, so that the term "pass" must be understood more in a

military sense, as an important point on a line of communication, than in a mountaineer's sense as equivalent to *col.*

Similarly, near the vale of Khanpoor, the last dying remnants of the folds in the Nummulitic limestone appear as long low limestone mounds parallel to the general strike of the country, and almost covered in by the recent river accumulations of the Hurroh.

A few sections near Hassan Abdal.

South-west of the Serh hill the Hurroh river takes a great turn to the north-west, and then again to the south-west, in the direction of Hassan Abdal. Between the latter place and Serh, there occur a few scattered hills, including those at Hassan Abdal, which, although really lying outside Hazara, may merit a few remarks since they occur along the railway route and cannot fail to attract the attention of any one visiting the district of Hazara. Wynne has inserted their geology on his unfinished map.

The temple-crowned hill stretching away east from the town of Hassan Abdal is shewn in section, fig. 34.

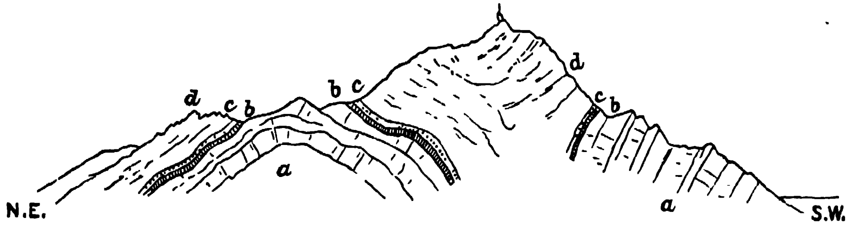

Fig. 34.

d—Nummulitic limestone.
c—Variegated sandstone.
b—Pisolitic iron-ore.
a—Trias limestone, well bedded.

An undulating anticlinal and synclinal fold are well seen. The Nummulitic limestone dipping north-east on the left of the section continues to form the north-eastern side of the hill the rest of the way to the point where the railway cuts across the strike on its way to Kala Serai. The Trias is extremely well bedded and weathers

in the usually well-marked way, and is quarried for the railway. The structure of the intervening bands of rock are as given below, fig. 35, in the gap north-east of the temple-crowned hill. Wynne has marked

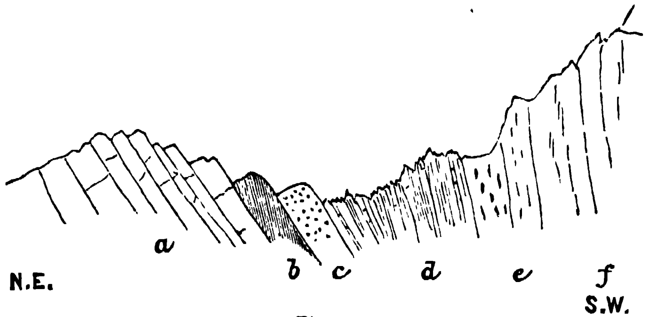

Fig. 35.

f—Nummulitic limestone.
e—*Echinolampas* zone, 3 feet.
d—Thin-bedded ochre-coloured limestone marls and shales full of gasteropods and bivalves, 10 feet.
c—Variegated sandstone, 6 feet.
b—Pisolitic iron-bed, 6 feet.
a—Trias limestone.

a band of Jurassics along this line, but I was unable to find anything resembling them. The pisolitic iron-bed certainly lies directly upon the Trias, and I can only regard it as of an horizon at least higher than Cretaceous. The *Echinolampas* zone is characteristic of this section and occurs crowded with that genus.

On the other side of the rail, in a north-easterly direction, the following section, fig. 36, is exposed in a bare hill-side :—

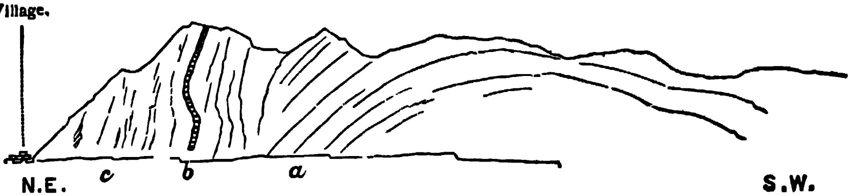

Fig. 36.

c—Nummulitic limestone.
b—Pisolitic bed.
a—Trias limestone.

Fig. 37 is a rough sketch of a block of Nummulitic limestone, which is the characteristic rock element of this great and well-marked zone.

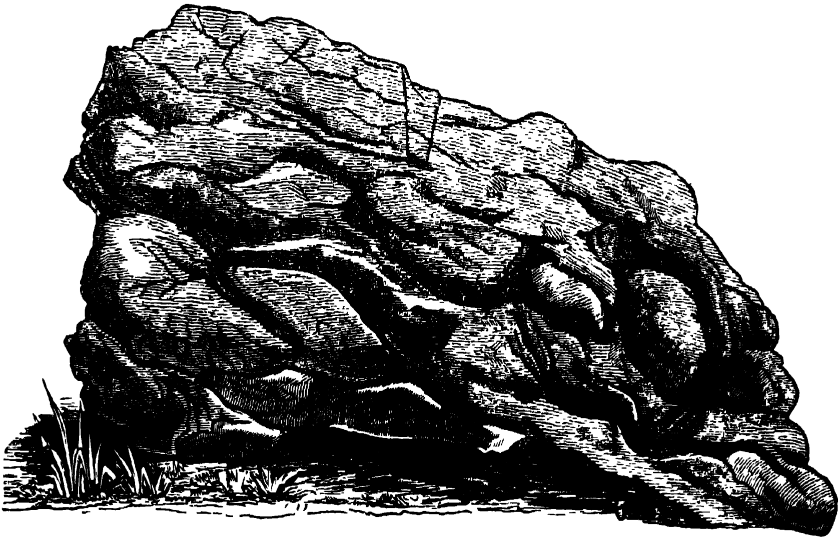

Fig. 37.

(4) *Summary of the Nummulitic zone.*

Taking a rapid glance over the Nummulitic zone as a whole we may note—

(1) That the sequence of formations is from Trias to Kuldana beds.

(2) That the Trias, so far as we can see down into it, does not differ in any marked way from the Trias of the southern parts of the Slate zone.

(3) That the Jurassics present two well-marked types, a northern and a southern, and that though they pass into each other, the line of passage is somewhat sharp and not always recognisable; also that whilst the northern type is characterised by an abundance of Spiti shales passing upwards into and overlaid by Gieumal sand-

stone (as in the Slate zone), the southern type is characterised more particularly by a calcareous element which appears to be developed both above and among the Gieumal sandstone.

(4) That the cretaceous band is remarkably well represented the whole way along the great earth-fold from Janomar to Moorchpoori, and that it dies out abruptly along the line of the Hurroh river, no trace of it or of its fossils being found at all to the south of that river or at any point in the zone of a corresponding strike-position.

(5) That the great Nummulitic formation throughout this zone, to which it gives the name, is remarkably developed, not only horizontally whereby it almost covers in the whole area, but also vertically, in which direction its thickness is very great. We may also note with regard to it the striking and peculiar change of facies in its lower part in the neighbourhood of the Chujjian Janomar, and Serh hill masses where it becomes distinctly arenaceous.

(6) That the Kuldana beds appear for the first time in the sequence of formations.

As regards the physical geology and surface sculpturing of the zone, much has already been said in the first part of this chapter devoted to the orography, but we may here recapitulate—

(*a*) Continuity and parallelism of strike, as in the Slate zone, but with gentle strike undulations and a somewhat rapid curving to the north as the Jhelum river is approached.

(*b*) A system of undulating earth-folds with accompanying fold-faults, and in some places a marked set of minor contortions and folds borne on the main folds.

(*c*) Valley systems divide themselves naturally into "longitudinal" and "transverse," and are either of the nature of deeply cut-down gorges or "rifts," or long shallow

valleys, occasionally expanding into wide valleys, but never into plains like the Abbottabad or Mansehruh plains.

(*d*) Hills not split up into central elliptical masses, with radiating spurs and of graceful build, as in the Slate zone; but combined into long steadily running strike ridges of squat and heavy architecture following the axes of the earth-folds.

(*e*) Denudation comparatively backward, as indicated plainly by the great convex ridge-slopes, by the longitudinal and transverse valley systems shewing as yet scarcely any sign of effacement or co-mingling, by the comparatively uniform descent in the general level of the country from the gulees to the Margalla pass, and lastly by the absence of great contrasts of elevation.

CHAPTER V.—DESCRIPTIVE GEOLOGY—*contd.*

(D) THE UPPER TERTIARY ZONE.

Orography.

The most southerly of the strike zones present in Hazara is the Upper Tertiary zone. It is bounded on the north by the Nummulitic zone, from which it is divided by a uniformly curving fold-fault; whilst to the south it is by no means confined to the area shewn in the map of Hazara, but extends for great distances over the Rawalpindi plateau, or Potwar, as far as the Salt-Range. The portion of it represented in Hazara is in fact a very imperfect sample of the zone as a whole, a mere fringe of it caught up along the outer margin of the last-described zone.

The Slate zone we have seen to be characterised by revealing no rocks below the Slate series. The Nummulitic zone in like manner reveals nothing below the Trias in its northern half, and nothing below the Jurassics in its southern half. Coming now to the Upper Tertiary zone we shall find that it carries out the same law by revealing nothing below the Eocene or Nummulitic strata. A

parallel law holds good as regards the highest exposed strata of each zone; for whilst the Nummulitics are the highest exposed strata of the Slate zone and the Kuldanas the highest of the Nummulitic zone, so the Siwaliks will be found to be the highest of the present zone (neglecting recent accumulations which are common to all the zones).

The narrowness of the belt of Upper Tertiary rocks represented in Hazara is such that very little need be said about them, especially as their more typical development in the Rawalpindi district has been already very thoroughly described by Wynne.[1]

Beginning with the zone as displayed in the neighbourhood of Murree, we find it composed of a single, nearly uniform ridge, which curves in a crescent shape round the south-eastern part of Hazara, one horn of the crescent trending north-east and north up the valley of the Jhelum, and the other trending south-west and west-south-west, and each lowering gradually in altitude as it does so. The full length of this Hazara belt of the zone is shewn in the two panorama views from Moorchpoori and Changla.

The hill station of Murree occupying some of the higher parts of the ridge is too well known as a hot-weather resort of this part of the Panjab for me to do more than briefly mention it here. Though it cannot vie with the gullees in its woodland scenery and the perfection of its water-supply, yet its proximity to, and accessibility from, the plains, and its greater roominess, have long ago established it as *the* hill station of the Panjab, second only to Simla. Notwithstanding that its imperfect water-supply (soon to be remedied) and the easy communication now established between the plains and Kashmir have somewhat detracted from its earlier popularity, it is still a favourite sanitarium for the hot months of the year. European shops, several hotels, a cathedral, and a brewery mark its prosperity and importance, whilst the location there of the head-quarters of the Panjab army, and the completion of the water-works, will ensure its future career as a hill station.

[1] Rec. G. S. of I., Vol. X, pt. 3, 1877.

The surface configuration of the Murree ridge and of its continuations N.N.E. and S.W. is extremely characteristic. Its general colour alone, which depends on the chocolate-purple clays and shales interbedded with the sandstones, is a very striking peculiarity, inasmuch as, if viewed from the north along the gullee ridge, the whole surface of the ground appears a reddish purple. The Murree beds, being one of the lower members of the Upper Tertiaries which characterise the Sub-Himalayan tract, do not here, as in many parts of the Himalaya, form a separate hill-range divided off from the main ranges behind by a low upland valley of the nature of the Dehra Dun and other similar valleys. The structure here is more nearly paralleled by that at the foot of the Naini Tal hills, where, as in this case, the Sub-Himalayan tract has become, as it were, welded into one whole with the older rocks behind and above it.

A conspicuous feature of this Upper Tertiary zone is the steady dip of the strata down against the faulted boundary to the north-west. This, as is usual in such a massive well-bedded rock as the Murree sandstone, gives a long gentle dip slope to the north, and a succession of picturesque scarps and secondary dip slopes to the south. Near Murree, where the forest is conserved, the northern slopes are fairly wooded. To the south-west again, where the level of this zone descends rapidly, the country is bare, and the low brown sandstone ridges, made up of disconnected pieces by reason of the streams which cut through them across the strike, possess nothing but low scrub-jungle, until dying away and sinking under a thin layer of alluvium towards Shah-ki-Moorpoor and Shah-ala-Ditta they pass into cultivated lands interrupted here and there by little rough stony lines of crags, where the harder bands of sandstone or pseudo-conglomerate stand out in relief. Towards the north-east, in the direction up the Jhelum valley, the Kaneir N. for some way marks off the north-west boundary of this zone. In this direction the hills flatten out at their top, lower gradually in elevation, and become covered with terraces of fields, one above the other, as at Dehvul, Beerot, etc. After the Kaneir N. leaves the boundary to join the

Jhelum, the above boundary line, which now runs north and south, is simply marked by a succession of low gaps or depressions on the side spurs as they descend from the older zones to the west. This position is an exact reproduction of the similar line of division between the Nahan beds and the Himalayan rocks of Ganwhar and Kumaun.

Sections in the Upper Tertiary zone.

Section near Dehvul.

The long narrow band of Murree beds which travels south down the right bank of Jhelum river shews very little of interest until Dehvul is reached. The whole way the sections, wherever visible, expose dips (whether normal or inverted it is impossible to say) at moderate angles towards the west. The sharpness of the boundary line between the Murree beds and the older rocks is emphasized by the way different members of the older zone come down against the fault,—in one place Infra-Trias limestone, in another Trias, and further to the south Jurassic or Nummulitic rocks.

Section in the Kaneir N.

West of Dehvul in the Kaneir stream-bed the Murree beds are separated from the older rocks of the Nummulitic zone by a narrow band of Kuldanas. The following sketch-section, fig. 38, shews the arrangement:—

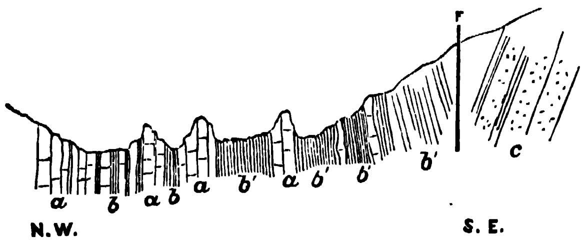

Fig. 38.

c = Murree sandstones.

b = Purple reddish shales and marly shales interbedded with *a* and *b*.

b = Grey and greenish-grey shales and marl sinterbedded with *a*.

a = Nummulite-bearing limestone.

Section near Murree.

The section near Murree has been very well described by Wynne, and for details I refer the reader to his paper.[1] The diagrammatic sketch-section given below gives the result of my own traverse across the section from Murree to Derriya Gulee.

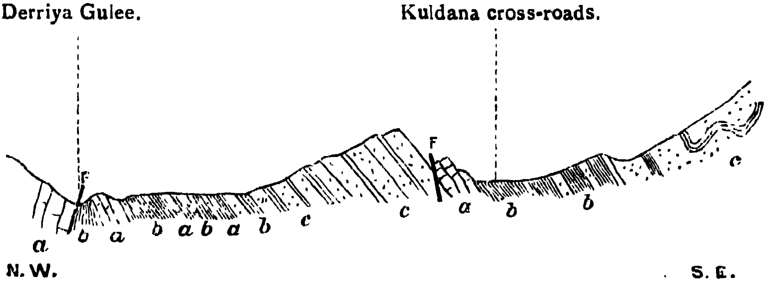

Fig 39.

c = Murree sandstone.
b = Purple-red, grey, and greenish-grey splintery shales and marly layers.
a = Nummulitic limestone.

The important point about the above section is that it shews a definite passage from the Kuldana beds up into the Murree beds near the 3½ milestone from Murree, the passage being of the nature of a gradual interbedding of the one set of rocks with the other, which is the most perfect and reliable form that a passage-bed can take. Hence I have represented on the map and in the section a normal junction here between the two sets of beds. By itself perhaps such a section would not be conclusive, especially since the exposures follow a rather narrow and disintegrating ridge, and the dips are high, but it will be remembered that in the gently folded rocks of Laichi Khun[2] this same zone of Murree beds follows in a perfectly normal and natural order above passage-beds resembling these Kuldana beds, whilst they in turn lie normally and naturally upon the Nummulitic limestone. Wynne from his remarks, page 69 of his last-quoted paper, was evidently of the same opinion. It will be noticed that north of the Kuldana cross-roads the dip of the beds is south-east and somewhat irregular, so that the general law that these younger Tertiaries dip towards the next zone to the north-west is here departed from.

[1] Rec. G. S. of I., pt. 2, pp. 68, 69.
[2] See p. 132.

The same series of beds have a strike continuation towards the north-east and south-west for a considerable distance. In the former direction, however, the rib of Nummulitic limestone and associated Kuldana beds, as exposed at the cross-roads, die out after about a mile, either by a fault to the north cutting them out, or for some other reason obscured in the gently flowing hill-sides. In the latter direction the rib of Nummulitic limestone continues by "Sunny Bank," "Clifden," Ghora Gulee, and Tret. At the last-named place it disappears from the map.

"Clifden" section.

A marked gap at each of these places indicates the junction of the hard Nummulitic limestone with the softer beds lying to the south-east. In the panorama from Changla (Pl. 10) this band can be followed by the eye from its position behind the Kuldana hill, where it is hidden in the drawing, across spur after spur given off from the Murree ridge as far as Tret. The Kuldana beds to the south-east of the rib follow only as far as Clifden, when they are apparently cut out by a fault. At Clifden and in the neighbourhood, these shales are impregnated with gypsum in anastomosing strings and veins. Gypsum also occurs in curved banded layers of grey and white colours. The mineral is not present in any abundance, but its occurrence at this horizon corresponds to the similar occurrences among the Kuldana bands already noticed in the Nummulitic zone.

Landslips.

The gentle northern slopes of the Murree ridge are sometimes subject to small landslips, or subsidences, during very heavy rain. In the autumn of 1891 one such occurred between the Club and Clifden, when a great bank-like mass of rocks, 80 to 100 yards long by 20 to 30 broad, and as many high, subsided, owing to the soft purple shales beneath the sandstone having been washed out by streams.

There is nothing more to be said about this Upper Tertiary zone as it appears in Hazara. An excellent description with sections of its extension to the south-east over the great Rawalpindi plateau will be found in the writings of Wynne, cited in the introductory chapter.

CHAPTER VI.—DESCRIPTIVE GEOLOGY—*contd.*

(A) THE CRYSTALLINE AND METAMORPHIC ZONE.

Orography.

It will now be necessary to recross the three disturbance zones which have so far been described, until we arrive at the zone made up almost entirely of crystalline gneissose and schistose rocks, or of other slightly metamorphic rocks. This zone lies on the north-west side of the Slate zone, and stretches away indefinitely in that direction. It has been left for description to the last because of its complexity; it presents in particular some difficulties of interpretation as to the age and stratigraphical position of certain metamorphosed sedimentary rocks which have puzzled every observer since the southern slopes of the Himalaya were first investigated.

This zone is very varied as regards its scenery and superficial characters. The hills rise sometimes to the very considerable heights of Bahingra mountain, 8,503 feet, and Ákhúnd Bábá, 9,170 feet; whilst out of the confines of the map with this memoir the snowy peaks, which close in round the head of the Khagan valley, attain an altitude of 15,000 to 16,000 feet. Again, the plains, such as the Pakli plain north of Mansehruh, the valley of Agror, the broad stretches of country only diversified by small hills like much of the Tanawal country, and the wide and sometimes deep valleys of the Indus and Jhelum with their tributaries, are examples of areas which are in a later stage of denudation than any we have yet seen. In other words, the contrasts of elevation in this zone are extremely well marked. We may also note that all tendency to a linear arrangement of the mountain-masses and their spurs has almost entirely ceased.

The country is wild and picturesque as we get among the higher hills. From about 8,000 feet upwards the hill-sides become well wooded with Deodars and other coniferous and temperate trees. The winter snows lie heavily on such ridges and summits, so that

villages and cultivation naturally cease about that level. The higher slopes are only used temporarily in the summer as grazing grounds or as passes from one valley to another.

This zone, especially in its northern parts, is but little known to European travellers or others. The higher valleys of Khagan are the especial care of the Forest Department. Agror and the neighbourhood are sometimes visited by the civil and political officers of the district. But north of that, in the direction of the Black Mountain, and beyond, the country-side is in the unsettled state that naturally belongs to a borderland where civilised rule and barbarism meet. Such parts are only accessible to an armed force.

Sections in the Crystalline and Metamorphic zone.

General remarks.

If the reader refers to what has been said pp. 4, 62, he will see that want of time and opportunity prevented my party from doing more than sample the great expanse of these rocks in the northern parts of Hazara. I shall not attempt, therefore, in what follows, to describe anything like a complete series of sections illustrative of the crystalline and metamorphic zone, but shall pick out a few here and there for description, which are of special interest. In the chapter dealing with the petrology of these rocks a good deal of detail has already been given. It remains here merely to shew by means of local sections their relative bearings to one another and to the unmetamorphosed rocks.

Sections in the Tanawal country north of Abbottabad.

The portion of the country to the north-west of the Slate zone is represented on the map as consisting of three formations: first the Infra-Trias, secondly, the "Tanols," and thirdly gneissose and schistose rocks. The following descriptions will tend to make their mutual relations clearer. There are three main outcrop-areas or bands of the Infra-Trias in this portion of Hazara, one running north-east—south-

west near Sobruh, another following the length of the ridge north of Teer village, and a third occupying a large space of country between Doodha mountain and Burkot Between them come other areas indicated on the map as *Tanols*, whilst to the north of both Infra-Trias and *Tanols* come the gneissose-granite and crystalline schists. In consequence of this it will be convenient first to describe each of these isolated Infra-Trias areas by itself, by reference to and by means of sections along particular lines.

Section across the Sobruh band of Infra-Trias rocks.

The low slate-hills north of Abbottabad, of which Hubeebuh mountain forms a prominent peak, have already been mentioned in the descriptive part of the Slate zone. It was remarked there that they shew no trace of any extra metamorphism until they approach the north-western boundary of the Slate zone, and that then the chief sign of such extra metamorphism was to be found in the quartz veins, from 6 to 12 inches across, which ramify through them. The absence of any limestone bands in the slates and of any prominent quartzose beds in this locality also make it impossible to unravel the complicated folds into which such thin-bedded rocks are thrown, for the simple reason that surface dips among shattered rocks of this kind are completely untrustworthy owing to surface deflection.

At Sobruh Gulee, about one mile north-west of the "T" of Thunnuh, the low slate country is connected with the higher rocky crags of the Infra-Trias band of rocks by a narrow little neck, or divide, forming a small pass between the head of the Miankhaki stream which flows south-west and a little stream which runs north-east by Puswal. Here the Slate series, slightly metamorphosed as described above, gives way to what at first sight appears to be a very normal section in the Infra-Trias. The slates for the moment are dipping south-east at fairly high angles, and above them the Infra-Trias crags are dipping north-west—a condition very much resembling that north of the Tanakki glen (see p. 100). A section across the band of rocks at this point is given overleaf, fig. 40. We may note

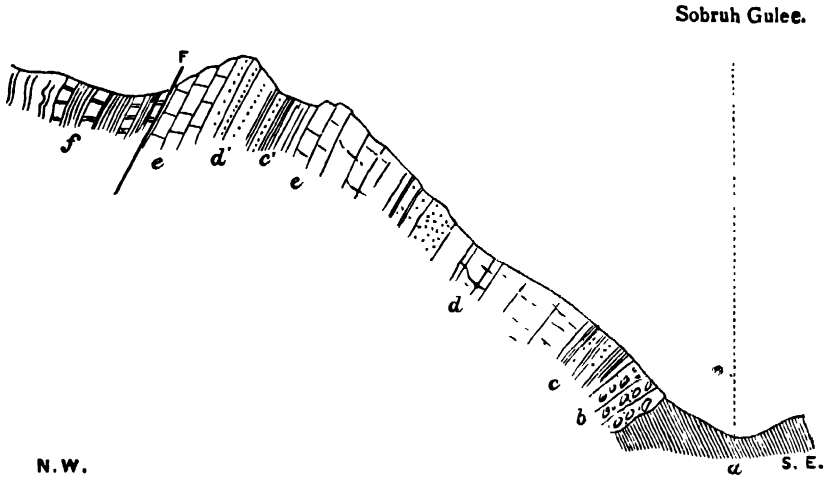

Fig. 40.

f=" *Tanols,*" Schistose rocks and crystalline limestone bands.

e=Infra-Trias limestone.

c'=Purple banded shales.

d'=Purple sandy limestone.

d=Coarse and fine purple, white, and grey quartzite and sandstone.

c=Purple shale.

b=Basal conglomerate, Infra-Trias.

a=Slate series.

with regard to that section, first that the basal conglomerate, which is about 30 feet thick, is made up of fragments of nothing but rocks such as the slates and quartzites below it. There is no trace here, as also there was none at Sirban, of gneissose rocks, or of any highly crystalline schists embedded as pebbles in the conglomerate. But the conglomerate as a whole has nevertheless assumed one of the first aspects that a rock suffering metamorphic change usually takes on, inasmuch as the pebbles have been turned round in their soft matrix, sheared slightly one over the other, and arranged with their long axes at a high angle with their original plane of bedding.

Abundant exposures along the stream running towards Puswal shew this aspect of the rock in many striking sections. Near that village also, and further on near Dhareh, the unconformable lie of the coarse conglomerate on the top of the slates is plainly indicated

by a waving and curving of the outcrop of the conglomerate as it inbays across the inequalities of the ground. In the opposite direction down the Miankhaki stream, the same conglomerate, lying beneath the quartzites, etc., is recorded by Hira Lal as having been recognised by him at a point on the map ⅛ inch south of the "l" of Mihal, beyond which, along the same line, down-stream, it does not occur, probably by reason of the covering of recent gravels hiding it from view.

The rest of the series above the Infra-Trias conglomerate comprises purple shales, somewhat cross-cleaved, purple and white quartzites, and sandstones, whilst the Infra-Trias limestone, though characteristic as to its composition and structure, is only of small thickness. In each direction along the strike these beds follow for some miles in natural order. Eventually this Infra-Trias band of rocks dies out to the south-west by reason of the overlapping of the recent valley deposits of the Miankhaki stream, and to the north-east by temporarily vanishing under the alluvium of the northern continuation of the Abbottabad plain.

There is no difficulty whatever in recognising that the section is similar in its lithology and its sequence of different rocks to the Sirban section, some five or six miles away, notwithstanding that a slight degree of metamorphism has supervened.

But it is when we come to the top of the Infra-Trias limestone to bed *e* of the section just given that a difficulty of interpretation creeps in. North of that point the section exhibits a great series of rocks which I at first believed to be metamorphic representatives of the Slate series, or at least of an older and different set of rocks, altogether distinct from the Infra-Trias as it normally occurs further south. These rocks are marked on the map as *Tanols*, a distinctive name invented by Wynne,[1] and which I have retained, because, as I shall shew later, they probably represent sedimentary accumulations with a characteristic aspect of their own, and though largely representing metamorphosed

Tanols.

[1] The word *Tanol*, though spelled differently, is really the same as Tanawal.

sandstones and quartzites of the Infra-Trias, probably also include with them other and older rock material along their northern edge.

Leaving the further discussion of the *Tanols* for the present, we will now take for consideration the band of Infra-Trias rocks which follows the line of the ridge north of Teer,—that is to say, the next band of these rocks which appears if we cross the strike at right angles in a north-westerly direction.

Sections in the band of Infra-Trias, north of Teer.

If the map be consulted it will be seen that the band extends from its north-eastern extremity near Tahlee in a long narrow outcrop trending S.W. by S. and expanding somewhat in its middle part south-east of the word Kootnalee. It then becomes accompanied by another parallel band of the same rocks which afterwards joins up with it north of Neelour. The joint band then, after continuing a short way, comes to an end a little west of Ulolee. To the north-west again there is another completely isolated patch of the same rocks running from the "B" of Bandah Loharah, spreading out near Durri, 3,567 feet, and thence continuing as a narrow ridge to the 2,943 feet hill, where it finally ends.

There are some considerable difficulties of interpretation appertaining to this outcrop area of the Infra-Trias rocks and the associated *Tanols*. On the north side of the great ridge of limestone in the low country between it and the Jurl N., the *Tanols* dip away towards the N.N.W. at 40°, lowering somewhat as the river is approached. These rocks consist here of a great series of coarse-grained schistose quartzites of white or faintly purplish colour,—rocks in fact agreeing lithologically in every way with the *Tanols* as defined in this memoir. At one or two places east of Kukotree there appears between them and the Infra-Trias limestone a thin bed of faintly metamorphosed conglomerate, which in many ways resembles the conglomerate at the base of the Infra-Trias, but which might also pass for one of the conglomerates, or more coarsely clastic beds which occur higher among the *Tanols*. Wynne in one of his sections[1] includes the conglomerate with the latter and divides it and them

[1] Rec. G. S. of I., Vol. XII, pt. 2, 1879.

from the Infra-Trias limestone by a fault. At other localities along this edge of the Infra-Trias band, as for instance on the "n" of Kootnalee and thence to the north-eastern end of the outcrop, the line of division is clearly a fault, and there is no development of the conglomerate at all, as for instance near Nukkeh.

Again, along the southern edge of this band along the space intervening between it and the next parallel band of Infra-Trias limestone there occur similar conglomerates, which, from their comparatively unmetamorphosed condition and from the associated purple slightly sheeny-surfaced slates and coarse-grained quartzites, seem still more likely to represent the true base of the Infra-Trias. These purple slates and conglomerates outcrop along a depression between the two Infra-Trias ridges, whilst the latter form steep craggy heights cut through in places by streams so as to form picturesque gorges, such as that above Teer village. The limestone itself is of the usual grey, sometimes cream, and flesh colour, and contains bands of chert.

South of the southern band of limestone I do not know of any occurrence of sandstone, purple slate, or conglomerate, which might represent the lower part of the Infra-Trias. On the contrary, the limestone along that line appears to overlie a set of white and purple and green banded schistose quartzites.

I give below a section, fig. 41, through the hill-mass from ¾ mile east of Kukotree to Kurm, and also another section, fig. 42, from near Kukotree to Teer. The only thing certain about these two

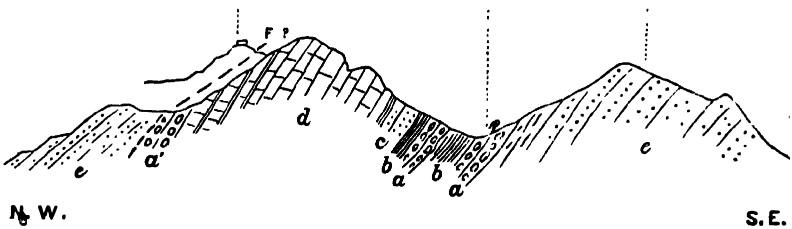

Fig. 41.

e = Tanols.
d = Infra-Trias limestone.
c = Coarse sandstone.
b = Purple shale.
a' = Conglomerate (schistose).
a = Infra-Trias basal conglomerate.

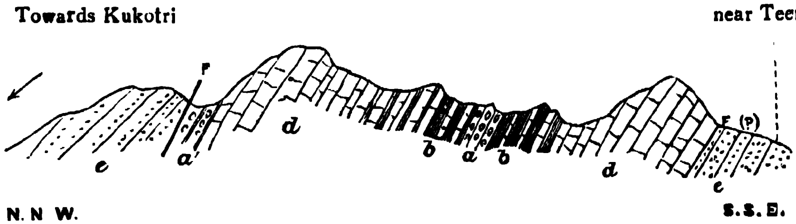

Fig. 42.

Index references as in fig. 41.

sections is that the limestone is Infra-Trias. The matters about which questions arise are—

(1) whether the conglomerates or one of the conglomerates marked *á* belong to the basal bed of the Infra-Trias, or to some other horizon, and

(2) whether the schistose quartzites north and south of the area, called *Tanols*, are altogether older than the typical Infra-Trias limestone of Sirban, or are altogether younger than it, or are contemporaneous with part of it.

The general lie of the beds gives one very little of a clue in these two sections, because the apparent dip is uniformly in one direction, namely, N.N.W. at high angles. It may be noticed, however, that in the section through Durri hill, 3,567 ft., the Infra-Trias limestone is bent into a rather narrow but sharp synclinal, whilst underneath the southern limb of the synclinal beds of purple quartzite, purple shale and conglomerate appear, very much resembling the normal section through the base of the Infra-Trias of Sobruh and Sirban. Below the conglomerate again are purple quartzites generally schistose and well-bedded.

Infra-Trias band extending from near Doodha mountain to Burkot.

Before we can advance nearer to the truth concerning these questions, it will be necessary to pass on to the next band of Infra-Trias as marked on the map, namely, the large area extending from near Doodha mountain to Burkot. Near Doodha some interesting facts may be noticed. Approached from the north by the village of Chunee Kot the much-weathered quartz-schists,

sometimes showing foliation or cleavage across the original bedding, are dipping (real dip) about 60° N.N.E. In the gap to the south of Doodha and between it and another hill further to the south, composed of the Infra-Trias limestone, there is an apparent variation of the latter near its junction with the quartz-schists. It becomes brownish, thinner-bedded, and interbedded with shales. There is no trace of any conglomerate. Towards the south in the direction of Jum the same limestone, in inverted synclinal folds many times repeated, seems to outcrop down the slopes and crags west of Beer. The impression obtained by traverses along the southern base of the Doodha hill-mass on the pathway from Kullungur *viâ* Jum to Kuchchee is the same,—an impression, that is to say, that fold after fold of the Infra-Trias follow one another lying in a much-disturbed basin among the schistose quartzites. The lower beds on the southern side are of a darker brownish colour, and there is a thin zone of sandy limestone at the base. Nowhere along this line of country, either to the north of the Infra-Trias outcrop or to the south, is there any occurrence of rocks which might be matched lithologically with the basal beds of the Infra-Trias, neither conglomerate nor sandstones. Near the Burkot end of the Infra-Trias outcrop in the vicinity of Pind and Khunda Khoosh the aspect of the whole mass of the Infra-Trias limestone in its relation to the *Tanols* is as if it lay above the latter, but was at the same time partly interbedded with it. The dip is gentle, at angles of 15° to 20°, shewing the limestone normally overlying *Tanols* near Hal and being in its lowest layers interbedded with it. Some beds of trap also occur here, apparently dyke rocks.

Near Hal along the road to Seree-Sher-Shah the same aspect of the rocks is very manifest. The dip gradually veers round from south to south-west, then south again, and finally south-south-west again. The strike thus runs nearly parallel to the Mangal N. The gentle dip of 25° to 30° increases to 40° as the direction changes. Some of the interbedded bands of quartz-schist shew a cleavage foliation distinctly crossing both rocks as in fig. 43.

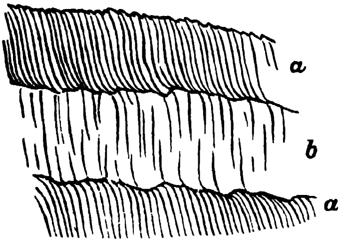

Fig. 43.
b = Limestone.
a = Quartz-schist.

The Sirun R. from near Seree-Sher-Shah exposes a continuous section in the Infra-Trias of this area. The river-bed is a very deeply eroded channel or gorge traversing across the strike from north to south. It is broken up into a number of pools of deep water between which a variable current runs dependent on the rainfall in the hills to the north, or on the moulting snow of Bahingra in the spring. As is usual in many parts of Hazara this river-bed is one of the main footpaths from village to village. The section exposed along it is one continuous series of fold after fold among the limestones, sometimes much mixed up with *Tanol* quartzites. It is from evidence here and on the neighbouring hills that I am inclined to think that many of the beds of the schistose quartzites among the limestones are due to a change of facies in the deposit, and that they here are contemporaneous with what is limestone in other parts.

The lower reaches of the Sirun R. between Beer and Soha also shew violent folds in the Infra-Trias limestone. Still further down-stream in the little hill north-east of Kuchchee the Infra-Trias is much more sandy than elsewhere. Its lower beds in particular are darker in colour, and the rock appears in the curious form of a pseudo-conglomerate. At first sight some of this material seems suggestive of rolled fragments of Infra-Trias limestone scattered through a sandy matrix, but ultimately abundance of passage forms were found connecting it with the ordinary Infra-Trias limestone which is generally much scored across and across by the peculiar form of weathering explained in chapter II, page 24. The cause of this appearance seems to be that the limestone, by the presence of more sandy material along with calcareous, became first concretionary, then a brecciation of the rock took place with a re-cement-

ation of the fragments and the production of what might at first sight be mistaken for a conglomeratic structure. This rock weathers into bold little heights crowning the hill-tops. The above is interesting as affording a definite proof that in certain places the limestone does become sandy by a gradual change of its material.

A few remarks on the Tanol schistose quartzite lying between and round the Infra-Trias limestone areas.

Intimately connected with and surrounding the three outcrop areas of Infra-Trias limestone come large areas occupied by the Tanols. They have been described in general terms before, and have been several times referred to in this chapter. These rocks are peculiar in many ways, and neither Wynne nor myself have been able to satisfactorily determine their relative position among the other formations of Hazara.

It is scarcely necessary to give individual sections illustrative of these rocks, because everywhere are they the same lithologically, and everywhere is the dip of their foliation and shear planes in towards the higher mountain ranges at not very high angles. They likewise do not vary much, nor possess any lithological sequence. Briefly stated they consist everywhere of a very great thickness of massive, rather coarse, felspathic, schistose quartzites, becoming faintly conglomeratic in places and pale white or cream coloured as a rule. In spite of the dynamic metamorphism that has so manifestly affected them, in common with many other rocks of this region, they have not the appearance that generally appertains to quartzites of very great antiquity. The separate grains of the rock are loosely aggregated together, not cemented by secondary silica. Thus structurally, these rocks are as far removed as possible from a glassy quartzite. In colour too they differ materially from the ancient, dark grey, purple, or greenish quartzites belonging to the Slate series.

Instead, therefore, of describing local sections in these rocks, I shall now summarise in a few statements all that I have been able to learn from a study of local sections in them:—

(1) In the field their outcrop areas are always confluent with

those of the Infra-Trias limestone. This is sufficiently illustrated by the map, where the two colours representing them lie touching one another on one or more sides. This seems to shew incontestibly that there is a connection of some sort between the two.

(2) From the section through the Infra-Trias band at Sobruh Gulee there does not seem to be any place in the series between the basal conglomerate and the limestones of the Infra-Trias for such enormous thicknesses of the Tanol quartzites.

(3) The sections through the ridge north of Teer, on the supposition that the conglomerate found in connection with the Infra-Trias limestone is the basal conglomerate, similarly give us no room in the series below the limestone for these great piles of strata. Thus we seem driven to conclude that the Tanols must be either contemporaneous or younger than the Infra-Trias limestone of the Sobruh and Teer bands.

(4) In the Doodha-Burkot area the Infra-Trias limestone in appearance seems to overlie the *Tanols* in the neighbourhood, but without any trace of a basal conglomerate or sandstone, but with quite different lowermost beds (see *ante*, p. 234). From this one might expect that the Doodha-Burkot Infra-Trias limestone band is younger than the two southern bands, and that much of what is called *Tanol* quartzites have a position between the two. This supposition on the whole seems best to fit in with facts.

(5) On their northern side the *Tanols* merge into the more ancient crystalline schists in a peculiar way. That shearing and reversed faulting has been the main agent in bringing this about I have no doubt, but actual proof is wanting. The northern junction line of the Tanols against the older schists is therefore vague and indefinite,

and has been left so on the map. No hard-and-fast boundary can be drawn.

(6) The fresh quartzo-felspathic material of which the rock is composed, and the coarseness of the grain, indicate a granitic source for it; whilst the slight metamorphism which the *Tanols* have sustained was doubtless due to the intrusion of the basic trap dykes among them. No single instance of the intrusion of gneissose-granite among them is known to me. They seem indeed pretty certainly to be younger than the gneissose-granite, and in all probability to have derived their material from it.

(7) In Jaunsar the 'Bawar' quartzites seem unmistakeably to be the equivalents of the *Tanols*. Possibly also the Boileaugunge quartzites, and much of the younger series of similar rocks described by me north of Dudatoli, are of the same age. In position and habit these rocks are very similar. It is likewise not impossible that the great Gondwana formation of Peninsular India is represented in part by the *Tanols*.

Sections in the Gundgurh Range.

The Gundgurh range has been briefly alluded to, p. 92. It is a somewhat isolated hill-range rising steeply on its south-eastern side from the Hureepoor plain and lowering gradually at its south-west termination towards the lower reaches of the Hurroh R. On its north-western side it lowers gradually to the level of the Indus which flows along its base. It is generally a bare and rough range of uninviting waterless slopes; but to students of Hazara history Sirikot fort is of interest as the place where Captain Abbott during the second Sikh war, August 1848 to February 1849, when cut off from all outside assistance, succeeded in defending himself from the rebellious Sikhs by means of the wild guerilla bands of Mahomedans which he collected.

Geologically this range illustrates very well the change of the

Slate series into metamorphic rocks. On the map the two colours representing these rocks have been shaded into one another, but it must be understood that the change is really more gradual than the conventional representation on the map would imply.

Section along the lower reach of the Sirun R.

The Sirun R. which rises in Bahingra mountain and whose course we have already followed geologically from Seree-Sher-Shah to Kuchchee, passes in its lower reach across the north end of the Gundgurh range and enters the Indus near Turbeluh amid vast plains of river-boulders. On its left bank it washes directly the foot of the Gundgurh range, and gives a continuous exposure of rocks, which, with the exception of a small rock near Turbeluh town, belong uniformly to the slate and schistose series,—that is to say, to the oldest rocks (as known for certain) in Hazara. On its right bank the Sirun river is bounded by terraces of river-gravels among which there are two low hill-ranges which just succeed in keeping their summits free from the covering of Recent gravels. The low range nearest the Indus, and running somewhat parallel to it, is coloured as belonging to the crystalline schists, whilst the more irregular and eastern group of hills is seen to be a continuation of the spurs of the *Tanol* quartzites descending from Doodha mountain.

How these *Tanols* are related in point of position to the older rocks all round them is not clear, as the gravel-filled valleys hide the secret.

Beginning in the lowest reach of the Sirun at the town of Turbeluh, and working up-stream along a very good road running parallel to the side of the river, we have a section as follows:—

At Turbeluh, quartzites and quartz-schists of undoubted *Tanol* facies appear first in the section, standing up in wall-like masses. Mr. Edwards and I on first seeing these rocks were inclined to place them with the metamorphic representatives of the Slate series, because we could see no good line of division between them and the rocks presently to be described. But later work among the hills to the south-west shewed that there is a sharp distinction between the two(see

on p. 247). Along the line of junction in a south-west direction Edwards found a crystalline limestone in two or more bands, which appears to continue to about the "h" of Turbeluh in the Sirun river-bed.

The next rocks exposed in the road section, after an interval of river-gravels, are finely crystalline schistose slates, of pale colour and shewing foliation surfaces filmed by mica. Then follow darker schistose slate rocks with ramifications of quartz-veins through them. They are considerably contorted on a large and small scale. Among the first mentioned pale schists there are some bands of hornblendic schists which may be foliated traps. They are in thin bands and stand up resisting weathering more than the rest of the rock. Foliation strike is about north to south and dip 50°—60°—70° W.

Wynne's erratics?

Due south of the "r" of Mehra and about 1¾ miles south-east of Turbeluh the section becomes of considerable interest by the appearance of the first of Mr. Wynne's so-called erratics.[1] I have before referred to these, p. 45, and stated my belief that they are not erratics at all, but only slightly displaced blocks, weathered out from an *in situ* vein. Such a statement at first sounds like a terrible indictment against Mr. Wynne's work, so in order to dispel such an idea I will at once say that (as I shall prove in a moment) the position is a peculiar one, a sort of geological puzzle, as if set by nature with the intention to deceive.

A little ridge-spur, running north to south on the east side of the "8" of 2,198, descends to the road. Looking up this we see a considerable amount of well-rounded river-boulders, a foot or more across, and generally of lens-shape—in fact exactly such as can be seen all over the boulder-strewn plains of Recent deposits near Turbeluh, and generally along the course of the Indus up-stream. But besides these we may also see a considerable amount of gneissose-granite (a rather fine-grained variety and without any noticeable porphyritic crystals) in huge masses, much split up by weathering, and lying on the spur and strewing the hill-side with fresh débris.

With regard to this I made out the following points:—

(1) There were blocks of immense size, and all but the smallest

[1] See Rec. G. S. of India, Vol. XII, p. 132, and section No. 3 accompanying the paper.

were completely angular, as if forming part of a crag or scarp.

(2) There was a general tendency among the blocks to shew a foliation-strike in one direction, namely along the crest of the spur.

(3) At a few places the ordinary schistose rocks *in situ* around had become more metamorphosed, and in addition contained veins of gneissose-granite 3—4 inches across.

(4) Although the obviously river-rounded pebbles or boulders before mentioned were scattered all over the hill-spur, and even over a considerable portion of the neighbouring spurs to the south-east, yet the large broken crags of the granite were only found along one definite line, namely, the crest of the ridge running north-north-east.

After a short thickness of somewhat arenaceous schists, with a thin bed 2—3 feet thick of limestone or dolomite, we notice an increasing metamorphism in the schists, until at a point on the banks of the river due south of Mohrut village there is another occurrence of gneissose-granite, under the same conditions as before. Low cliffs on both sides of the river give an exposure as shewn, fig 44. It is undoubtedly a vein intruded among the schists; although owing to

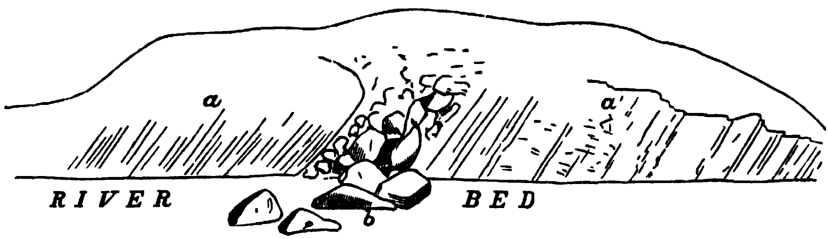

Fig. 44.

b = Gneissose-granite vein, weathered into fragments.
*a*¹ = Thick-bedded schists.
a = Thin-bedded schists.

its weathering into huge blocks which have rolled down the slope the section is somewhat hidden. We found beneath the fallen blocks 3 or 4 distinct veins of the granite, varying from a few inches

to a foot or more across, penetrating the schists in a devious way. No very prolonged search was necessary to decide that the rough angular blocks were practically *in situ*. In order to place the matter beyond all doubt we searched along the strike of the rocks up the hills to the south, and we found at the village of Tandoola in a section 8 yards long and 4 broad three distinct veins of the granite about 1 foot wide as represented in fig. 45. South of Tandoola the veins appear to die out, and a band of crystalline limestone of rusty-brown colour follows the same line of strike amongst the schists.

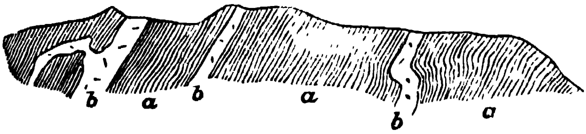

Fig. 45.
b = Gneissose-granite veins.
a = Schist.

South of the band of gneissose-granite in the river-bed, the schists are penetrated by a trap dyke 4 ft. wide, and there is another just before crossing the Tandoola N. Then, on the second "7" of 1,787, there occur in the river-bed more huge boulders of the granite very slightly rounded. Tracing them south in the direction of the right bank of the Tandoola N. we find representatives of them running up the hill-side towards the "n" of Tandoola.

About 1 mile on from this place there are on the hill-side several bands of coarse-grained trap striking north to south and dipping due west about 40°. The schists here are also of a dark colour. About ¼ mile further near the last "a" of Tandoola there is another very suggestive occurrence of the granite. It seemed to me to be a crag jutting out from the hill-side, so much smashed by weathering that its actual boundaries could not be seen. Exactly in the same line of north-to-south strike there is on the south side of the Sirun R. another accumulation of masses of the rock, and furthermore, in the river-bed itself, there are large masses of it. There is nowhere clear evidence of the rocks in contact with the granite, but I conclude from the linear arrangement of the blocks parallel to the general

strike (and across the river valley) that they are at or quite near their *in situ* place.

Observations by Hira Lal further indicate the persistence of these outcrops of gneissose-granite. He found, near Mohrut and Mehra (beyond Suarbee), large quantities of erratics of the rock, one of which was 42 feet in diameter. The blocks here lie in and among the stretches of gravel which hide their proper relations.

The following diagram, fig. 46, will assist the reader in comprehending the positions of the so-called erratics and their obviously related positions as parts of intrusive veins.

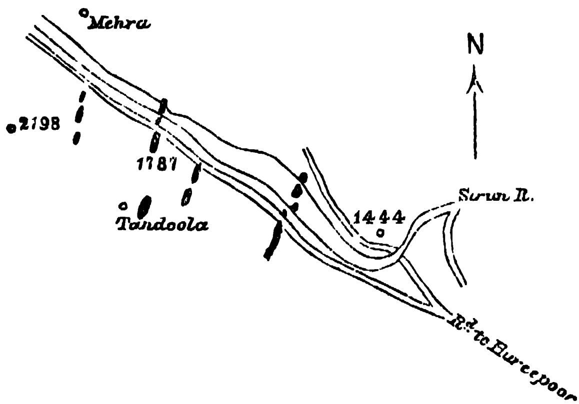

Fig. 46.
The black dots represent outcrops of the gneissose-granite.

Thus it is certain from the evidence I have adduced that the so-called erratics of the left bank of the Sirun R. are nothing but the ragged feather-edge of a series of veins of gneissose-granite among the older schistose slates. The right bank being a gravel plain, shews no rock *in situ* whereby the continuation of these veins in a N.N.E. direction could have been followed out in detail. The whole position, on the face of it, is obviously a puzzling one, and liable to misinterpretation. Nothing but a detailed examination of each occurrence could possibly have given the clue to the right interpretation.

The point to be borne in mind and the lesson to be learnt are simply this, that a massive coarsely crystalline rock, in weathering out of a thin-bedded rock, is extremely liable to be left in the

form of rough and tumbled blocks which at first sight may very well look like erratics, especially when the whole occurrence is partly masked by recent gravels.

At page 46 I have hinted that a similar explanation may suffice to account for the erratics found south-west of the Gundgurh range, in the portion of the country between Hassan Abdal and Attock. It may be stretching an application of the same explanation too far to include the Jhand erratics also among the same list, but it is a point worth bearing in mind by anyone visiting the locality again.

Other sections in the Gundgurh range.

I do not propose to describe in great detail the rest of the Gundgurh range. Wynne has given three sections across it in his paper (Rec. G. S. of I., Vol. XII, p. 114), and to these I refer the reader. The south-eastern side of the range, which becomes a steep scarp in its central part, exhibits a foundation of the slate series, the slates becoming slightly schistose as we reach the watershed near Rous and Budda. Among the slates there are limestones of the same type as the two kinds found near Lunguryal, which, in proportion as the surrounding slates are less or more metamorphosed, are themselves less or more marble-like.

Some of the slates and associated limestone bands become impregnated with graphitic matter: one marked band of graphitic shale or schist lies on the N.W. side of the limestone bands S. E. of Rous. This material is said by Wynne to be known to the natives as "surma lurri," but according to information from the jaguedar of Rous this name is the name of a place, and has no connection with the black graphitic layers, nor is the stuff itself used as a substitute for surma (antimony) for the eyes.

The slates are fine-grained and shew prominent banding in the lower parts of the range to the south-east. The ridge near Rous is composed of more arenaceous beds.

If we cross the ridge here and journey down the north-west slopes towards the Indus valley, we simply pass over rocks the metamorphism of which becomes slightly more pronounced as we advance.

Of the numerous limestone bands that appear at the south-west

end of the range some disappear to the north-east, others continue, and gaining in importance, occupy a large area on the high crest of the ridge near Pir Than. I give below, fig. 47 and fig. 48, diagrams of the puckered and frilled limestones which are found on the slopes of this hill mass, referred to also p. 54.

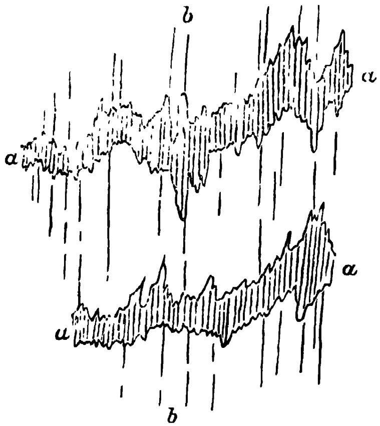

Fig. 47.
aa – Lines of original bedding.
bb – Lines of cleavage and re-arrangement.

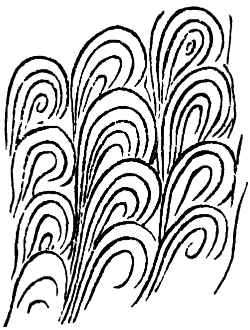

Fig. 48.

Near Chooeean some of these limestones, which have here attained a great thickness, bear a strong resemblance to those of the Infra-

Trias. I was unable to satisfy myself whether any of the latter were really present or not.

The graphitic schists, which have continued in this direction from the south-west end of the range, continue, and form a marked band well seen on the north-west edge of the great limestone mass between Chooeean and Bandee. A good deal of dark trap, in the form of masses intrusive along the bedding, is also found among the graphitic schists and among the limestones (see p. 81).

As the high crest of the ridge lowers again in a north-easterly direction, the massed limestone bands separate again once more into distinct bands, four of which persist to within 4 or 5 miles of the Dore R. near Thupluh.

The north-eastern half of the Gundgurh range is much wider than the rest, owing to the appearance of *Tanol* quartzites in great force south of Mohut. The section from Mohut to Sireekot up the Mohut N., exhibits an enormous thickness of quartzites and quartz-schists, easily recognised as belonging to the *Tanols*. They are thrown into one immense synclinal with a N. E.—S.W. axis, the dips being as high as 40° or 50° on each side. In the valley N.E. of Choutrai there is a sharp change, and a very schistose conglomerate, much folded and repeated by faults, appears beneath the *Tanols* and dipping towards the north-west. It is extremely deformed by pressure, and more nearly resembles the Blaini conglomerate of the Simla neighbourhood than anything I have seen. With it is associated a small lenticular band of limestone, doubtless of Infra-Trias age. The same band of limestone may be traced at intervals round that part of the range lying north-west of the Duruh N. It appears west of Umur Khanuh, and again between Sobruh to Mohut in a continuous outcrop parallel to the bank of the Indus R. This limestone does not anywhere pass downwards into purple quartzites, sandstones, shales, and conglomerates, as in the typical Sirban area. On the contrary, it appears interbedded with white and pink *Tanol* quartzites. At Mohut there are two distinct bands of the limestone as shewn in fig. 49.

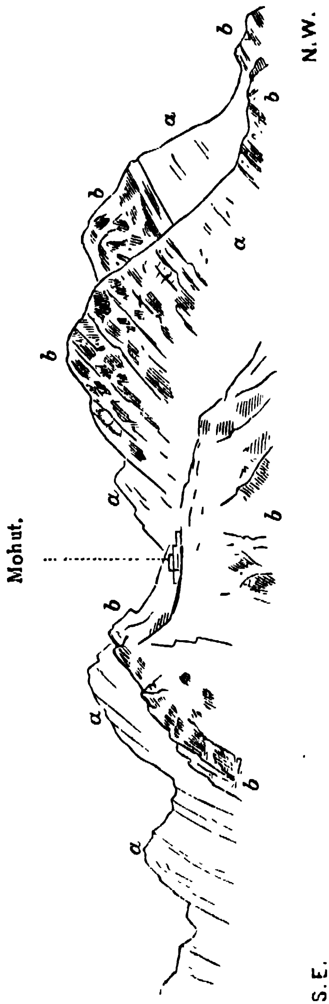

Fig. 49.

a = Pinkish and pale greenish-white quartzites.
b = Dark flesh-coloured Infra-Trias limestone weathering dark brown.

Sections in the Black Mountain.

The southern part of the Black Mountain, which was that visited by me with the expedition of 1891, adjoins Tanawal on the north, and

Agror on the west, whilst it has as its western boundary the Indus R. It is really only a small patch of country of about 64 square miles, descending in steep ridges and ravines from the crest of the Black Mountain ridge to the Indus. The steepness of the slopes may be gathered from the fact that a descent from 8,160 ft. to 1,500 ft. takes place within a horizontal distance of 2½ miles. Again, the drop from Makranai to the Indus is from 4,550 ft. to 1,400 ft. in one mile, which gives a gradient of 3 in 5. The highest peaks on the main ridge are Machai, 9,825 ft., and Ákhund Bábá, 9,170 ft., which, with all the higher parts of the same, are covered with dense forest of Biar, Paludar, etc. The slopes nearly everywhere steepen downwards near the bed of the river, a fact which, together with the large scale of this profound valley, may be realised when it is remarked that during the expedition the brigade taking the hill route *viâ* Tilli and Ril had to plough their way through deep snow, whilst the river column marched through rain and mud, the operations of the one being generally completely hidden from the sight of the other.

A word is perhaps necessary to explain why I have taken such an out-of-the-way bit of country for detailed description when I might have addressed myself to the more familiar and easily accessible parts of the country in Hazara itself. The reason is that having been deputed with the Hazara Field Force, my movements were limited within the area occupied by our troops; and as no one could say (when the operations began) how far afield we might or might not go, we could not know that we should be confined to the aforesaid 64 square miles. Such, however, turning out to be the case, I could do nothing but study this small area in as close detail as possible. Hence it comes about that it forms one of the portions of the crystalline and metamorphic zone which I have sampled and taken as typical of the whole.

The rocks exposed in the Black Mountain, and also along the approaches to it up the Indus river, belong to the divisions (3), (4), and (5), or the more intensely crystalline rocks, presumably representatives of the Slate series on the main, and with great intrusive

masses or sills of gneissose-granite and dykes of a plagioclase-augite rock (see p. 51). None of the metamorphosed Infra-Trias or *Tanols* are known to be represented.

These rocks from a petrographical point of view have been described in the chapter on the stratigraphical elements, and I shall now give some account of the rocks (as briefly as possible) shewing their geotectonic inter-relations.

Section from near Budhauruh to Derbund.

The first section I shall take (indicated in the margin) is by way of linking up the observations in Tanawal with the Black Mountain. Budhauruh lies north of the Doodha mountain *Tanols*, and the section from it to Derbund *viâ* Lalo Gulee is as follows:—As far as the latter place it crosses somewhat diagonally over the outcropping edges of the beds whose strike is generally N.W.—S.E. About the position of the first "h" of Budhauruh there are dykes of decomposed trap which are continuous with those near the "n" of Budgiran. They occur apparently interbedded with quartz-schists and with a single thin layer of white crystalline marble. Further on, nearly as far as Sunvai, the rocks become more markedly metamorphic and schistose, with a few trap dykes, and with large quantities of graphitic schists streaking the hill-sides with black. With them is some hæmatite, and an efflorescence of alum in thin lines near the stream below Sunvai.

At Sunvai there occur some very thick beds of white and buff-coloured crystalline limestone, which outcrop up the hill-side in a north-westerly direction. On the road north-east of the "i" of Sunvai, the first bed of very much decomposed gneissose-granite sets in. It is not very coarsely crystalline and is not porphyritic. It is very distinctly foliated in places.

Then follows, as far as the second little gulee on the road north-west of the "S" of Sunvai, a very irregular plexus of fine bands of trap, gneissose-granite, and mica-schist, alternating with each other. Individually mapping these bands, except diagrammatically, would be impossible.

Further north-west again, beyond the little gulee just referred to, the distinction between the schists and the gneissose-granite becomes less marked, and we arrive among rocks with mica-schist as a basis, and among which the granite in ¼-inch bands has been injected as if under enormous pressure, and in a most complicated way (see p. 68). These continue the whole way down to Lalo Gulee, but vary a little in the relative importance of the different rock-elements. In this direction also the strike begins to bend round more to the N.N.W., until at Lalo Gulee itself, in the valley of the Indus, the strike is more generally N.—S., and sometimes E. of N.

The fine bands, veins, or fingers of gneissose-granite which we have met with between Sunvai and Lalo Gulee are not continued towards the south-east. They would appear to die out in a feather-edge like the similar veins on the Sirun R.

Beyond Lalo Gulee up the Indus to Deruh the strike continues N.—S. or generally with the course of the river, which it here seems to have influenced. The dip of the foliation planes is W.

The river-gravels above Lalo Gulee are washed for gold in the usual native fashion common in India.

As far as Derbund the same rocks continue, the strike varying between N.N.W. and N.N.E., and the hill-sides descend towards the river in huge foliation planes. Between Derbund and Phuldar nothing but schists are visible, slightly garnitiferous, and ill-exposed beneath the Recent gravels.

Sections along the Indus R. above Derbund.

Travelling up the Indus from Derbund, as far as Shingri in the Black Mountain country, our course is northwards. Beyond that *viá* Kotkai and Bakrai to Bimbal[1] and Dedal, the river bends like an S. (beginning at the bottom). The general strike is continuously northwards sometimes to the E. and sometimes to the W. of it. The rocks exposed are of the usual kind found in the crystalline and

[1] The Black Mountain names are spelled in the modern way.

metamorphic zone. Schists with basic dyke intrusions are most common as far as a little to the west of Kotkai; after which the granite appears in some fairly thick and many very thin bands, all running parallel to the foliation strike of the schists and of the trap dykes, which are foliated at their margins.

Notwithstanding this, many examples are to be seen of the dark dykes actually cutting across the edges of the foliation planes of the schists and gneissose-granite, as for instance three miles N. of Goomti, also opposite Gházikot and Kunhâr (see fig. 50).

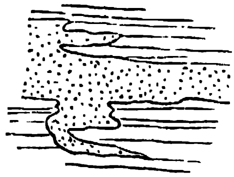

Fig. 50.

Graphitic schists like those mentioned in the Gundgurh range are found on the hill-sides S. of Kotkai, about 1,000 feet above the river-bed, also near Bimbal in the bed of the river associated with crystalline limestone.

During our course along this section one is very much impressed by the intricately parallel way in which the schists are banded with thick or thin veins of the granite or of the basic trap. The grey schists, the white granite, and the dark green or black trap form a 'complex' of parallel layers distinctly visible, but far too numerous to be accurately rendered on any map.

At the junction of the Shal N. with the Indus there are some interesting features shewn in the river section which I will endea-

vour to describe briefly. The following sketch-section, fig. 51, is 100 yards in length and represents the main points to be observed.

E. Fig. 51. W.

In it *a* represents gneissose-granite, non-porphyritic, with lenticular-tabular foliation parallel to that of the other rocks and to the junction planes of the other rocks: *b* represents interbandings of the gneissose-granite with a dark schistose or gneissic rock: *c* (specimen lost in transit). These interbandings are so complete that the granite bands gradually die out and towards the east become mere veins crossing, and parallel to the foliation of the gneissic rock (see also diagram, p. 76): *d* is a compact non-foliated trap of greenish-black colour and with no veins of the granite invading it: *e* is a schist as described, p. 58. Its foliation is parallel to that of the other rocks: there are some few veins of granite *a* in it also which gradually increase in number and fineness. The veins ultimately fill the rock and vary in size from a thickness of 1 foot to 1 inch or less.

Before leaving the valley of the Indus we must not forget to note the recent river-gravels which present some features worthy of attention. The hill-sides beyond Shingri and Kotkai rise steeply from the river-bed in great convex slopes steepening downwards. The bottom of the valley is sometimes narrow and gorge-like, but sometimes it spreads out into a wide plain 1 to ½ a mile across. The bottoms of these valleys are filled with gravel and alluvium which are spread out as terraces, or which slope down as detrital fans from the mountain glens. In the wide valley at Derbund, and between Shingri

and Kotkai, there are in addition a large number of huge boulders of gneissose-granite, sometimes as much as 20 feet in diameter. These are scattered about among the alluvium, and a view of them from the hill-sides is rather peculiar, as they seem to litter the ground as if thrown there in sport by some supernatural agency. I could find upon them no evidence of the action of ice, nor does there seem much difficulty in rationally accounting for them without that agency when we know that the high ridge immediately above the valley near Pailam has the gneissose-granite *in situ* in great thickness.

Well-rounded river-boulders occur in horizontal beds at certain places on the hill-sides and at great heights above the present river-bed. For instance, at Diliari and on the hill-sides at Bimbal these beds are 2,000 feet above the river. They are undistinguishable from the similar gravels now in the process of formation by the Indus R. The amount of erosion of the present river indicated by them is therefore enormous. As a parallel case further down the river I may here refer to the very similar gravels situated at the summit of the hill behind Kalabagh in the Salt-Range.

Blown sand in the form of gentle dunes occurs in the wider parts of the valley as at Towara.

Sections across the main ridge of the Black Mountain.

If we ascend the hill-sides to the east of the Indus by a series of E.N.E.—W.S.W. parallel routes such as those from Kotkai to Tilli, from Ghazikot to Makranai and Abu fort, from Bakrai to Seri, or from Darbanrai to Kand, we pass directly across the strike of the various rock elements of this crystalline zone. They all exhibit a foliation dip in towards the higher crest of the ridge, at the usual fairly steep angles in the lower part of the valley, and slackening off towards the crest of the ridge. The lower slopes are a continuation of the rocks as we saw them in the valley of the Indus. But as we ascend, the rocks first become a more pure and simple mica-schist, sometimes garnitiferous, and then there follow a few thin bands of gneissose-granite which are a prelude to the in-coming of a very broad and massive band or sill of the same ½ mile in width, and which, outcrop-

ping N.N.W.—S.S.E., characterises the line of country from Tilli *viá* Ril, Naranj and Bukal to Najorian. There is then a narrow interval of interbanded gneissose-granite and schists, and then follows a second thick sill of gneissose-granite, similar to, but more massive than, the last, and taking a parallel line from the west scarp of Panjigali *viá* Landai to a little west of the high crest (8,160 feet) above Kand. Trap dykes at certain places, especially on the ridge west of 8,160 feet summit, interrupt the granite in parallel very thin outcrops. The rest of the way up to the crest of the Black Mountain ridge is over schistose rocks invaded and permeated by narrow strings of the granite and by isolated crystals of felspar, but without any very important bands of massive gneissose-granite.

Inasmuch as the crest of the ridge from Panjigali takes a north easterly course to Bampurgali, after which it again travels north- or north-north-west, it is clear that the north-easterly trending part traverses diagonally across the strike of these thin-bedded permeated and injected schists (as described above). The highest summit of the ridge, Ákhund Bábá, 9,170 feet, caps the middle of this part of the ridge and represents, as far as one can see, the top bed of this great crystalline ascending series, which is here rather arenaceous and with fine interpenetrations of the granite. For, east of that summit, we appear to pass through a descending series of the same order as on the west side up which we have come, and finally at Bampur we arrive again at great massive beds of the gneissose-granite, the representative of one or other or both of the Tilli-Ril or Panjigali-Landai bands. This is plainly indicated on the south-east slopes of the Ákhund Bábá part of the ridge by the Bampurgali band passing continuously *viá* Sumbalbat, Kotli Maidan, and Rahimkot to Pabalgali, thus completing half an ellipse of outcrop.

Below Rahimkot the strata turn over and dip in the opposite direction. The long straight ridge going towards Thati and the two long straight parallel ridges going towards the summit of Bahingra seem to follow the general strike of the crystalline rocks,— *i.e.*, N N.W.—S.S.E.

I give below, fig. 52, a section through the main Black Mountain ridge, crossing the summit of Ákhund Bábá and the general strike :—

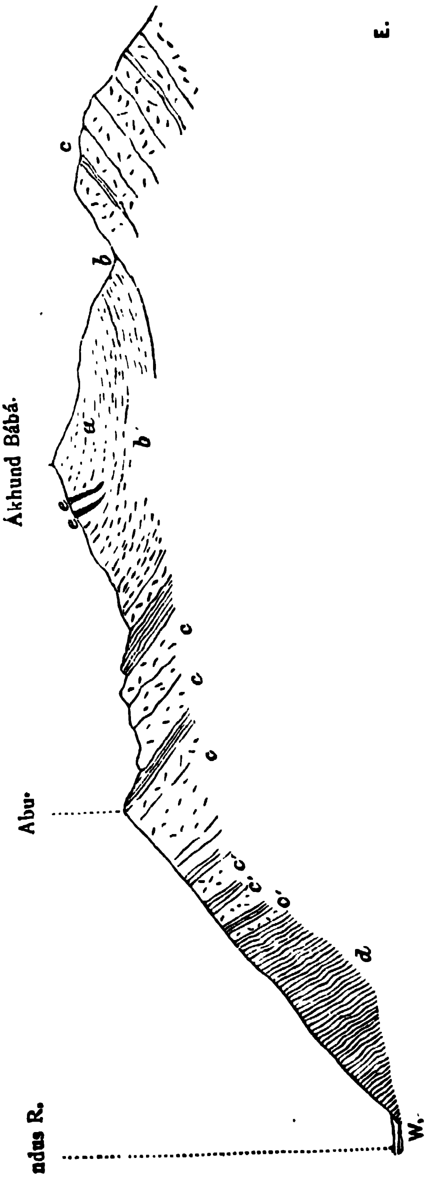

Fig. 52.

e = Trap dykes.
d = Mica-schists with garnets in places.
c = Thin bands of well-foliated gneissose-granite.
c = Gneissose-granite in strong bands showing all the types from foliated to massive.
b = Schist with garnets in nests and with veins of gneissose-granite.
a = Fine-grained arenaceous schist, black mica in small flakes and with very fine interpenetrations of gneissose-granite veins.

The following points may be mentioned with regard to the sections, the salient structural features of which I have just sketched:—

Beds of earthy hæmatite and limonite occur 1 mile E. of 8,160 feet hill on the ridge towards Machai. They are evidently secondarily formed from the magnetite in the rock which locally becomes somewhat important. The same is found also near Torani where it had been worked in the deserted village of Sokar. The same band probably crops out on the Ákhund Bábá—Seri road, as pieces were brought me by Major (now Colonel) Greenstreet, R.E., from that locality. Large schorl crystals are found in the white granite at Panjigali. Due west of Shingli on the Panjigali ridge there is a trap dyke shewing five-sided columnar structure. The form of surface denudation which goes on in the higher parts of the ridge is well exemplified at Bampur gali where, slightly below the loose snow but where snow had recently been, there were large flows of solidified mud of an ochre colour and sometimes in a semi-liquid condition. They seem to represent the disintegrating surface of the crystalline rocks which has been slowly formed under the snow and kept prisoner for a long time, instead of being carried regularly away. When the snow melts a discharge of great volumes of such mud down the valleys must take place.

Crystalline and Metamorphic zone as a whole.

From the samples I have given of this zone, and from such knowledge as we possess of the parts of it not referred to by me we may come to the following conclusions with regard to it:—

(1) That it may be divided into an inner and an outer tract, the outer one nearer the plains including examples of metamorphosed Infra-Trias and "Tanols," and the inner one ascending towards the greater ranges shewing nothing but the metamorphosed Slate series in complex combination with veins, ribs, and sills of gneissose-granite.

(2) We have thus two metamorphic series, a younger and an older, and whilst the latter is penetrated and altered by the granite and also by the subsequently intruded basic

dykes, the younger series (Infra-Trias and "Tanols") is only penetrated by the basic dykes.

(3) That as regards disturbance with crumpling of the strata, the thin bedded older metamorphic series is the one that has suffered most severely along the outer margins of the area where the granite veins are absent or of minor importance; but that further inwards towards the higher ranges the same rocks have been (in a measure) protected from contortion and folding on a large scale, owing to the great resistance offered by the thick and massive sills of gneissose-granite. Thus it is that the higher hill masses exhibit gentle dips in the foliation of their schists, and also in regard to the junction planes between them and the granite, which, as has been frequently stated, are generally parallel to each other; hence it is also that the higher isolated crystalline massifs exhibit a qua-quaversal dip all round them of their component strata, and hence it is that there are such great variations in the strike, with the occasional persistence over relatively large areas of N.W.—S.E. strikes (as in the Black Mountain).

(4) That such an arrangement is not peculiar to this part of the northern backbone of India, but has been noticed and described by me in previous papers on the crystalline and metamorphic rocks of the Himalaya, especial reference being made to the Chor mountain, Kaloghari (Lansdowne) and Dudatoli; whilst Mr. Medlicott long ago commented on the same peculiarity.

(5) That as regards the younger metamorphic series the crumpling and folding, though fairly intense, is distinctly less than that of the older series wherever the two are found together.

(6) Comparing the zone as a whole with its neighbour zone to the south (the Slate zone) we must notice, above all, the absence of any authenticated evidence for any rocks younger than the Infra-Trias—whilst they only occur

along its southern border—and the fact that it gives us somewhat abruptly, but with perfect finality, a set of metamorphic and crystalline rocks occupying corresponding areas and altitudes to those in the Slate zone which are characterised by the historical rocks ranging from the Slates to the Nummulitics.

CHAPTER VII.—GENERAL CONSIDERATIONS.

In the foregoing chapters the geological structure of each of the zones has been given in considerable detail. It must not be imagined that every structural item, as collected in the field, has been presented to the reader. On the contrary, the great mass of material facts have, I hope, been judicially sifted, so that only such as are of most intrinsic merit in explaining the geological history of Hazara, or necessary to establish the geological features as laid down on the map and sections, have been brought forward. Still the amount of detailed description is considerable, and it would have been very hard indeed if no results of a general nature could be deduced from them.

Detailed accuracy of map.

As a preliminary to such I may point out that the geological boundaries were laid down on a map twice the scale of that accompanying this memoir, and that even then much detail had to be suppressed, which, wherever possible, has been inserted in the sections. No one knows better than a geologist within what wide limits geological accuracy as represented in maps can vary, but I think I may, from the considerations given above, and without egotism, claim that the boundaries of the various formations are as accurately reproduced on the map as its scale would allow. In most cases my notes and sections would have sufficed to produce a much more detailed delineation had the scale and topography of the map admitted of it. Thus, any superstructure of deduction and generalisation that I shall now attempt to raise on the material furnished in the foregoing chapters must be understood to have a reasonably firm basis in facts as represented

on the map. As to whether these deductions are sound or not the reader must judge for himself; but he may rest assured that they are not vitiated by that worst of all fault, *viz.*, distorted, inaccurate, or merely guessed at stratigraphy.

The four disturbance zones compared.

In the chapters just concluded a number of comparisons have been instituted among the four disturbance zones, which tend to show that each of them has an individuality of its own marked by many features peculiar to itself. It will be necessary to examine a little more closely the varying physical aspects under which each zone appears. For the sake of clearness, the four zones with their alphabetical signs, and arranged in their geographical order, are recapitulated here:—

N.-W.

(A) Crystalline and metamorphic zone.

(B) Slate, or Abbottabad zone.

(C) Nummulitic zone.

(D) U. Tertiary zone.

S.E.

(A) may furthermore be known as the innermost zone, and (D) as the outermost.

Relative elevation of the earth's crust in the different zones.

It has already been insisted on that the zones differ from each other in a marked way by the varying levels at which certain formations occur in them. As an instance I may repeat that in the Slate zone the Trias generally occupies a rather elevated position, forming the first storey so to speak of the hilly superstructure and reposing on the Slate series as a foundation, whereas the same formation in the Nummulitic zone holds a much lower place being itself the structural foundation of that zone; whilst lastly, in the U. Tertiary zone it is completely buried out of sight. I shall now state the case generally for any formation.

If in any zone a number of vertical sections be taken, each extending from the highest point visible on a prominent ridge down to the lowest point attainable in a stream-bed, and if from all these

sections a mean or average section be calculated, we shall find that each formation in the resulting mean section occupies or spreads through a definite vertical range. Similarly, if for any other zone another mean vertical section be calculated, this resulting section will be found to differ from the previous one in the relative levels or vertical ranges of each of the composing formations. In fig. 53, diagrams *a*, *b*, *c*, *d*, represent four such mean vertical sections, de-

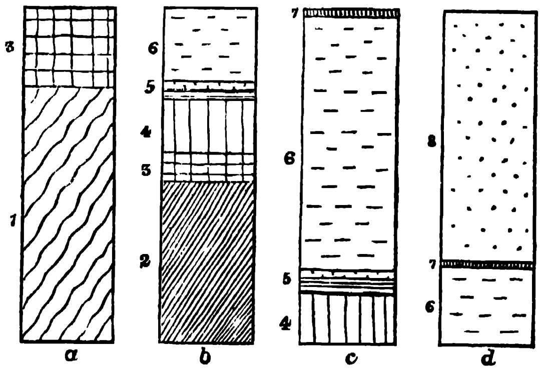

Fig. 53.
8 = *Murree* beds.
7 = *Kuldana* series.
6 = Nummulitic limestone.
5 = Jura-Cretaceous.
4 = Trias.
3 = Infra-Trias.
2 = Slate series.
1 = Crystalline schists, etc.

duced respectively for the zones A, B, C, and D. With reference to their construction which here has been chiefly of a graphical kind, it may be remarked that greater accuracy in the resulting mean position of each formation might be obtained if necessary, and the greatest possible accuracy if a large map showing true contours were available. The general principles involved are, however, independent of such extreme accuracy.

For the sections *a*, *b*, *c*, and *d*, a very simple law is seen to hold good, namely, that the mean level of a formation rises as we proceed through the sections from *d* to *a*, or sinks as we proceed in the opposite direction. For instance, following out the Nummulitic formation we see that in *d* it occupies the base of the section, in *c* a middle position, in *b* an uppermost position, whilst in *a* it is unrepresented. Similarly, following the Infra-Trias formation, it is at the top of the section in *a*, it occupies a middle position in *b*, and is lost to sight in *c*: and so on for any formation.

An expansion of the above law applied to the zones themselves states that more upheaval of the earth's crust as a whole has taken place in zone A than in zone B, more in B than in C, and more in C than in D.

Relative compression of the earth's crust in the different zones.

Having seen that the disturbance of the earth's crust as represented by the relative elevation or upheaval of each of the zones is a quantity which varies with decreasing amount as we travel from N.W. to S.E., we may now enquire whether there is any corresponding variation in the amount of that disturbance as represented by the compression (folding, faulting, cleavage, shearing, etc.) sustained by the various zones. Taking the simplest case first we will compare the outermost and innermost zones with each other (zone D with zone A). As has already been explained, zone D, or the U Tertiary zone, is very imperfectly represented in Hazara where only the northern edge of it is included. Its typical aspect is only seen away from the hills towards and beyond Rawalpindi. There, as recorded by Mr. Wynne, the greater part of the zone is a plateau with gently rolling and sometimes nearly horizontal dip, whilst not infrequently ranges of small hills or elevations are composed of nearly unaltered symmetrical anticlinals. Secondly, all the rocks of this zone are soft sandstones, sand-rock, shales, or conglomerates, entirely unaltered in a metamorphic sense, and only differing from Recent accumulations of the same kind by being slightly indurated and by their gently inclined positions. Contrast the gentle undulations of this zone with the highly flexured condition of the crystalline and metamorphic zone A, as depicted in the various sketch-sections in the body of this memoir; contrast the plain flat surface of the one with the rugged and precipitous character of the other; and lastly, contrast the hardly consolidated sandstones and conglomerates of the one with the cleaved, sheared, faulted, and metamorphosed condition of the other. If this be done we shall be obliged to conclude that as regards the outermost and innermost zones there is a great difference in the amount of the lateral compression indicated by each, and that

it is incalculably greater in the latter than in the former. Thus the zone that indicated the greatest elevation exhibits also the greatest compression and *vice versa.*

Between zone A and zone B, though we might not be able to trace out contrasting amounts in the coarser effects or larger foldings of the strata, yet, descending to the minuter structure of the rocks, we must at once be made aware of the marked way in which zone A has yielded to compression in this respect as compared with zone B. What were slates originally in A have become divided through and through by a completely new set of foliation planes along which a fresh mineralization has taken place; what was an ordinary conglomerate (the Infra-Trias) composed of great blocks and boulders oriented in any way in a fine shaley matrix has become a *slate*, or a faintly glistening schist. In some extreme cases as we have seen (p. 55) earth movements with compression have acted on this easily-traced rock to such an extent that the flattened and drawn-out pebbles would with difficulty be recognised did not stratigraphical evidence point conclusively to its former condition. As regards the coarse sandstones and limestones belonging to the same epoch, zone A tells a similar tale of differential movements of the minuter particles of the rocks, specimens from which at Bilihana mountain and the Gundgurh have been particularly described (Chapter I, pages 56, 57).

But though these effects of compression vary greatly in zone A, they are absent or very nearly absent in zone B; and though in the Gundgurh hills and near Gurhee-Hubeebooluh there are signs of a gradual passage from the slates to the metamorphic schists, the line of change, albeit a gradual one, is extremely well-marked and shows no fluctuations on either side, that is to say, no recurrence or interbeddings of metamorphic rocks with non-metamorphic rocks. In other words, the change from the Slate zone B to the Metamorphic zone A, though gradual, is rapid and irrevocable.

I do not think I need urge more proofs to establish the statement that zone A, which showed a greater general elevation than zone

B, also shews a greater compression, as evinced in the finer structural details of the rocks.

Taking now for consideration the different amounts of compression marking the Nummulitic zone C from the U. Tertiary zone D, we shall find no difficulty in recognising the great contrasts in the nature and amount of the folding of these respective zones. It would only be tedious to insist again on facts abundantly illustrated in the descriptive part of this book, as regards the Nummulitic zone, and on the facts as represented in Mr. Wynne's sections for the U. Tertiary zone. Here, as before, the more elevated zone C is more compressed than its south-eastern neighbour D.

It is only when we come to contrast the Slate zone B with the Nummulitic zone C, in the above respect, that opinion halts for a moment to consider; and it would not be perhaps fair to draw too rigid a conclusion from the figured horizontal sections which are not continuous with one another. Nevertheless, I think that, disregarding details, we may draw a general conclusion to the effect that the flexures and fold-faults in zone B are grander, straighter, and tend (especially along the northern sub-zone) more to an isoclinal nature than in zone C. As illustrating this we may note the long straight outcrops coinciding with the strike of the rocks in the former, and the winding and V-ing outcrops which predominate over much of the area of the latter. At least it cannot be said that the law is reversed in this case.

Thus we find that just as the amount of the disturbance of the zones, gauged by their general upheaval, decreases in a south-easterly direction, so also does their disturbance, inferred from the lateral compression they have suffered, steadily and regularly decrease in the same way zone for zone.

Relative amount of denudation of the earth's crust in the various zones.

The relative difference between the different zones in the matter of the amount of denudation which they have suffered has been considerably dilated upon already in the descriptive orography and summary of each zone. It has been abundantly shown that the zone most backward in this respect is the outermost

or U. Tertiary zone, that its north-western neighbour the Nummulitic zone is somewhat less backward, whilst the Slate zone, and the Crystalline and metamorphic zone, respectively show signs of a more complete or prolonged denudation.

Altogether then, taking the zones in order from A to D, that is to say, from north-west to south-east, we find them to be in unison as regards the amount of elevation, compression, and denudation which they have suffered : zone A has been most elevated, most compressed, and most denuded; whilst as we travel south-east through the other zones in order we find that they have successively been less elevated, less compressed, and less denuded.

Two ways of accounting for the above facts.

There are two principal views which may be held as to the cause of the above three-fold progression; we may either regard it as the joint result of a varying *intensity* of the activities at work, that they were more energetic in zone A than in zone B, and so on ; or, allowing their intensity to have remained constant throughout the whole area, we may account for the different progressive results by supposing that the *time* during which those activities were at work varied instead, a view of the matter which would range the zones in order of age A > B > C > D.

A third view compounded of the other two is of course possible also.

For the present we must leave the question an open one until we have considered some other points which bear upon it.

Remarks on the boundary faults to the south of each zone.

Turning to a consideration of the boundary faults which lie on the south side of each of the three more northern zones of disturbance, we may note specially about them :—

(1) Their parallelism to the *general* strike of the adjacent formations : a fact which marks them as being of the nature of fold-faults, or highly dipping thrust-planes.

(2) Their characters as being lines dividing one zone from another: thereby indicating how the extra elevation and compression of each zone found relief by the packing up

of the strata, and by sliding over its neighbour zone to the south-east.

Boundary fault between the Upper Tertiary and Nummulitic zones.

Let us take each boundary fault and consider its history. Inasmuch as the least elevated, least compressed, and least denuded zone, namely, the U. Tertiary zone, lies chiefly outside the area covered by this memoir, and as it is the datum line from which we are reckoning the varying disturbances of each zone, we need say nothing regarding the relations it bears to the Recent zone of *no* elevation which lies to the south of it. Any fault or line of flexuring, such as is represented by the scarped edge of the Salt Range, is at present in an incomplete and transient stage; and as such, it would not bear comparison with the others until the time when the Recent deposits are themselves upheaved into another disturbance zone. But coming to the great winding fault between the U. Tertiary zone and the Nummulitic zone, which has been known right along the Himalaya as the main-boundary fault since Mr. Medlicott first discovered its existence and interpreted its meaning, we are able to draw some important deductions from it. Its general course in Hazara, curving up the bed of the Jhelum, and the return curve on the other side of the Jhelum in Kashmir, together with the behaviour of the Upper Tertiary rocks towards it, have been detailed in the last chapter but one. For details concerning its further course along the Himalayan mountain-foot the reader may consult the references given below.[1] All the evidence gathered concerning it tends to show that it was not paroxysmal, but that it grew gradually as the Himalaya extended their provinces by incorporating with them the deposits now forming the Sub-Himalaya. Similarly, all evidence goes to show that this fault approximately marks the limit of deposition for the Murree beds of the Upper Tertiaries in a northerly direction. In Hazara we seem to possess a particular proof of this in the long, thin, synclinal strips of the Kuldana beds enfolded in the Nummulitic zone. Their uniform narrow width precludes the idea

[1] Medlicott—Note upon the Sub-Himalayan Series in the Jamu hills, Rec. Geol. Surv. of India, Vol. IX, pt. 2, 1876, and Mem. Geol. Surv. of India, Vol. III.

that at least several thousand feet of Murree sandstones were once superposed on them, and forces the natural conclusion that at or about the beginning of the Murree stage, at a time when little more than the purple and gypsiferous Kuldana beds had been spread over what is now the Nummulitic zone, the latter was gradually upheaved, and a limit of deposition formed for the succeeding thick beds of the Murree sandstones. At the same time the preliminary phase of the main-boundary fault began. As the Nummulitic zone grew in height, the undulating strata wrapped the Kuldana beds in synclinal folds and the boundary fault became more marked as a line of differential earth movement, on one side of which the undulating Nummulitics were forced southwards and upwards, and on the other side of which the accumulating Murree sandstones were forced northwards and downwards.

How long a time, geologically speaking, a boundary fault such as this took to form, cannot be very accurately gauged, but that it began in early Murree times, and practically ended when the younger Siwalik sand-rock and conglomerates were depositing, seems a safe conclusion. Apart from the special case here considered, I take it for granted that a fault of this description cannot be of a paroxysmal kind; it has nothing in common with a normal fault; it bears no relation whatever to a rock-fissure or crack that we might conceive of as having been formed by a sudden snapping or rupturing of the rocks. It seems to me a weak point in geological nomenclature that such lines of relative earth-movement were ever classed with faults at all; but that they have been makes it all the more necessary to scrupulously define them.

Boundary fault between the Nummulitic and Slate zones.

Turning our attention now to the next boundary fault to the north-west, namely, that between the Nummulitic and the Slate zones, we find, from the presence of Nummulitic limestone to the north of it as outliers in the Slate zone, that that fault cannot be regarded as a limit of deposition for the Nummulitic limestone. On the other hand, from the absence of Kuldana beds north of the fault, it seems pro-

bable that it was a limit for those beds, their argillaceous and estuarine character bearing out the same view. Hence we must date that boundary fault as having been in the main completed since the Nummulitic limestone was formed, and probably before or just at the beginning of the deposition of the Murree beds.

Boundary fault or line of weakness between the Slate and Crystalline and metamorphic zones.

The next boundary fault, or line of weakness, between the Slate and Metamorphic zones, cannot be dated so accurately. It must, however, be younger than the Infra-Trias, and it most probably went on forming *pari passu* with the deposition of the Trias. It nowhere shows itself as cutting or truncating any rocks younger than the Trias.

Thus, each boundary fault is older as we travel north-west across the zones; and since we must regard them as the great lines of relief which allowed the much folded rocks of each zone to respond to the growing horizontal compression by sliding *en masse* over the younger deposits which were forming to the south, we have here an argument for the gradual upheaval of the various disturbance zones at successive geological epochs. Thus as regards age we find it true that zone A > B > C > D.

Cause of the different degrees of upheaval, compression, and denudation in each zone.

This practically answers the question propounded above as to the cause of the different degrees of upheaval, compression, and denudation which mark the disturbance zones; inasmuch as the different effects of the tangential stresses tending to compress the earth's crust laterally, may be most simply understood as due to the different periods of time during which they have been at work: in other words, the older the zone the more it has been elevated, compressed, and denuded. The above hypothesis seems altogether more reasonable than one involving a different local intensity of the tangential forces, an assumption in support of which no arguments can be brought forward drawn from the rocks themselves, and one which requires a further assumption concerning the direction and origin of those tangential stresses.

Enquiry as to how far the above zonal structure is continued out by the limits of Hazara.

From the foregoing, the division of Hazara into zones of disturbance, and the regarding of these zones as marking different stages of upheaval of the earth's crust, seem warranted by the facts of the case. But Hazara is only a small slice out of the great chain of mountains that surround India on its north-west and north sides. For the above generalizations to possess any meaning with reference to the whole of that chain, it is necessary to show at least a probability in favour of their applicability to adjoining portions of it. In order to do this, reference must be made to those geological papers and maps which deal with the neighbouring areas west and east of Hazara. But even then the fitting of a theory which depends entirely on close mapping on the scale of 1 inch = 1 mile, to work done by other men is somewhat unsatisfactory, especially considering the small scale of the mapping of such parts of the Punjab, Afghanistan, and Kashmir as have been examined by them. In pointing out, therefore, certain possible ways by which my zonal divisions established in Hazara, may be carried along in a westerly and easterly direction, I wish it to be understood that I am not dogmatizing, but merely *suggesting*. It is more than probable that these suggestions will afterwards require much retouching to bring them into harmony with facts.

Zonal structure in W. Punjab.

Mr. Wynne's map and descriptions of part of the Punjab[1] shew that the U. Tertiary zone, as defined by me, continues with all its characteristics in a westerly direction. Its northern faulted boundary is shewn as such passing along the southern foot of the Chitapahar for about 35 miles, and crossing the Indus half way between Attock and Khushialgurh. A line of faulting to the south of this, running by the Khairemurut ridge, and through Jhand to the Indus below Khushialgurh, marks off a subzone in the southern part of the U. Tertiary zone; and a similar line of faulting, with a southern sub-zone to the east of the Jhelum, is described by Lydekker[2] on the inner side of the Siwaliks, and separating them generally from the Murree beds to the north: but

[1] Rec. G. S. of I. Vol. X, p. 3, 1877.
[2] Geology of Kashmir, p. 86.

this by the way. Throughout the whole of this western continuation of the zone, even in its more northern and more disturbed sub-zone north of Jhand and the Khairemurut range, the folding of the rocks, their upheaval and relative denudation have been insufficient to expose anything lower than the Nummulitic stage.

As regards the continuation of my next zone, the Nummulitic zone, in the same direction, we find that the line of its northern boundary is hidden under Recent accumulations of the Hurroh and Indus rivers until the Cherat hills are reached, when its normal faulted boundary again appears. To the south of that line this continuation of my Nummulitic zone shows, as in Hazara, the same distribution of the formations from Trias to Kuldana beds with the same noticeable absence of any recorded exposure of the slates which presumably lie at some depth below the zone, but which the present stage of the upheaval, disturbance, and denudation has yet failed to bring to the light. As to any sharp division, faulted or only sudden, between the Slate zone and the Crystalline and Metamorphic zone in this direction information is wanting.

On the whole, then, it is my belief that, regarding the continuation-area west of Hazara, through the medium of Mr. Wynne's map and sections, we may see every likelihood that it too preserves many of those peculiarities of structure which I have defined as belonging to and characterising my zonal divisions in Hazara.

Continuation of the same structure into the Saféd Kóh Range.

If reference be made to the comparatively recent paper by Mr. Griesbach on the geology of the Saféd Kóh,[1] we shall find, I think, abundant evidence shewing the persistence in this direction of a zonal structure similar to that of Hazara. At page 105, Mr. Griesbach considers the north skirting ranges of that mountain chain to be composed of old metamorphic with palæozoic rocks, much altered strata following as a belt south of it, and with possibly some strata of older mesozoic age wedged as narrow strips into the belt of the latter. He considers the main axis of the Saféd Kóh to belong probably to the older palæozoic group, whilst lastly, the southern skirting ranges

[1] Rec. G. S. of I., Vol. XXV, pp. 59 *et seq.*

are composed chiefly of the mesozoic group with preponderance of its younger systems.

The points of resemblance between the structure of the Saféd Kóh and Hazara are therefore as follows:—

(1) The old metamorphics with palæozoic rocks are only found in the northern belt of the northern skirting range.

(2) The younger systems of the mesozoic group are only found in the southern skirting range.

(3) In between these two there is the central range, and the southern part of the north skirting range, made up of older palæozoic with possibly strips of older mesozoic wedged into them.

The survey of the tract has not been carried out as yet in sufficient detail to admit of closer comparison.

Zonal structure in Kashmir.

Turning now in an easterly direction to Mr. Lydekker's work in Kashmir, it is necessary to remember with caution that whilst Wynne's map to the west is $\frac{1}{4}$th the scale of my map of Hazara, that of Kashmir by Lydekker is only $\frac{1}{8}$th of the same scale, or 16 miles to the inch. I have referred above to the fact that the faulted boundary dividing the U. Tertiary zone into sub-zones continues along east of the Jhelum into country examined by Lydekker. The northern representative of this sub-zone in Kashmir is not, however, differentiated from the Nummulitic zone, as in Hazara. So far as one can see from Lydekker's work the northern half of this zone and the Nummulitic zone are combined into one great zone, characterised chiefly by the presence at the surface of the ground of the Murree beds, but with numerous inliers along various lines of older rocks from Nummulitics through Jurassics and Trias. Here, then, we find a conspicuous difference between the fringing structure of the mountain-chain to the west and east of the Jhelum R. respectively. The discrepancy, it must be noted, does not however weaken my argument for the periodical and gradual upheaval of the mountain mass east of the Jhelum, but merely shows a slightly different combination of the activities which produced it.

As regards the northern boundary of this combined Nummulitic and Murree zone we see that it exactly reproduces the boundary to the north of the Nummulitic zone in Hazara, inasmuch as it presents the appearance of the Murree beds, dipping down against and in direct contact with the older Pre-Tertiary rocks of the "middle mountains" of Lydekker. At pp. 94-95 in his memoir, the above author endeavours to shew that the junction in question, though unconformable is a natural one of deposition. Although, I think, it might be possible to dispute this point with a considerable amount of success, it is not necessary for my argument to do so; for the great feature of this "main boundary" line, as it was originally called by Medlicott, is that it generally coincides with an approximate limit of deposition. Thus the Pre-Tertiary rocks north of the combined Nummulitic and Murree zone show signs of belonging to an earlier phase in the upheaval of the mountain area, inasmuch as, whether we believe that folding with production of a fold-fault occurred along the line of junction or not, we must admit that the Pre-Tertiary zone of the "middle mountains" is an older one in point of formation and elevation if not in the matter of compression by lateral forces.

The Slate zone in Hazara we have found to be characterised by the presence of outliers of rocks from Trias to Nummulitics, in contradistinction to the crystalline and metamorphic zone, which shows nothing above the Infra-Trias rocks; and to be divided more or less sharply from it. In Kashmir it does not seem possible from the published descriptions to establish any such division, but it is clear from Mr. Lydekker's book that no metamorphic representatives of rocks from the Trias upwards are known.

Zones of disturbance in Garhwál and Kumaun, Sub-Himalaya.

If we travel further afield from Hazara along the foot of the Himalaya to Garhwál and Kumaun we shall find there, as I have described in my memoir on the Sub-Himalaya of those parts, that exactly similar zones of disturbance are to be met with. As the subject was treated in some detail in that memoir, I need not do more here than refer to it.

Concluding remarks under this head.

Without compromising ourselves, therefore, by making any statements as to the age of the upheaval and building of the Himalaya—as no two writers can agree as to the right limitation of the terms, seeing that, day by day, age by age, and period by period, it expands in one direction and diminishes in another—we may I think consider it as proved that different parts of that range in the form of longitudinal strips or blocks of strata, have had different histories, and played different parts in the evolution of the mountain-range as we see it now ; and that on the whole, the southern aspect of the range has been fashioned, not all at once, but piece by piece; so that, like a house that has been added to at different dates, it shows by signs of age, by variety in the style, and by a change in the building material, the different stages through which it has passed before becoming the still-unfinished edifice of to-day.

The great crystalline granitic or gneissic axis of the Himalaya.

In taking account of any general theory of the Himalayan mountains or their western continuation in Hazara, there is one great factor that cannot be overlooked, one indeed to which our attention naturally turns when contemplating them, namely, the great crystalline core which forms the line of the central snowy peaks. About the exact nature of this crystalline core there are opposite views. Some observers regard it as an ancient gneiss, at least in great part; whilst some believe it to be, at least largely, a foliated granite. I do not propose to argue out a question of this kind, which indeed in these days seems to be a gratuitous undertaking, inasmuch as in certain ultimate stages of both rocks modern opinion seems to be inclining to the view that they may not only be structurally constituted alike, but, within limits, functionally act alike.[1]

So far as Hazara and such parts of the higher and lower Himalaya that I have seen are concerned, the rock if originally a gneiss, must have been so heated up as to get at least into a plastic state in which it was capable of considerable movement under pressure along lines

[1] See papers by Dr. A. Lawson, Ann. Rept. Canadian Survey 1887, p. 33, and by G. Barrow, "On an intrusion of a Muscovite-biotite gneiss in the S. E. Highland of Scotland" Quart. Journ. Geol. Sec. Lond. Vol. XLIX, p. 330, Aug. 1893.

of least resistance. On the other hand, if the rock is really a granite all through, that is to say, the product of a molten magma drawn from some unknown underground reservoir, then its activities as a granite, its function as an intrusive igneous rock, have been kept well under control.

Its mode of intrusion among the strata.

Probably the first idea of many people after superficially studying the Himalaya would be to regard the great crystalline axis as having been the cause of the upheaval of the mountain mass, the prime mover, which bursting through the other rocks wedged them apart and folded and contorted them.[1]

But studied in detail this theory does not hold good for a moment. There are no violent disruptive phenomena connected with the gneissose-granite, as manifested in its position among the metamorphic crystalline schists. On the contrary, it appears rather to have quietly and under enormous pressure accommodated itself between the schistose strata, in part consuming them probably as it went along, but leaving here and there undigested fragments as inclusions near the margin. Everywhere in the mountains its parallelism as regards foliation and the margins of its beds has been remarked on. In many places it occurs in great beds which may be followed in their course through a mountain massif, just as we might follow a thick stratum of some sedimentary rock or a flow of an igneous rock. I cannot think that any one, after studying it in detail, would come to any other conclusion than that, if conceded a granitic origin, it was formed as great laccolites, deep down below the surface of the earth, under such enormous pressure of the superincumbent rocks that an eruptive function was generally denied it, and it had perforce to follow the resulting lines of least resistance, that is to say, along the divisional planes of the rocks among which it was squeezed.

[1] From a copy of the Presidential address to the Geologists' Association for 1895 by General McMahon, kindly sent me by the author, it would seem that this belief is entertained by at least one who has claims to be considered much more than a superficial student of the Himalaya. Yet, among the many well reasoned-out conclusions in that paper, I venture to still reiterate that on this one point I think General McMahon is completely wrong.

As to how this enormous concentration of acidic magmas along the area now known as the Himalaya took place, and what were the particular forces which first conduced to it, I cannot presume to offer an opinion. Nor is it absolutely certain of course that there ever was any such concentration of the material in its molten condition. These granitic foundations out of which the Himalaya were ultimately to rise may have been common to a very extensive area, by no means confined to what is now the Himalaya.

One fact must not be lost sight of in discussing this granitic or gneissic rock, namely, its uniformity of petrological characters right through the Himalaya from end to end, so far as observations have gone. The particulars I have given, page 62 *et seq.*, as to its mineral composition, and structural features are not applicable to Hazara alone, but certainly to the whole of the Himalaya that I know, and most probably to all the rest.

Uniformity of petrological characters.

If we turn our attention to the south of India, of which I have had some recent experience, what do we find is the mineral composition of much of the gneissic tracts there? We find the felspar may be variously coloured and of species ranging from orthoclase to anorthite[1]; we find the crystalline aggregates varying enormously in the size and condition of the grains and in the resulting appearance of the rocks; we find the ferro-magnesian minerals may be not only the micas, but also that hornblende and hypersthene play a great rôle in these rocks; and we find moreover that in certain areas certain bands across the country are characterised by the predominating presence of one of these minerals and certain other bands by another. There is no uniformity in S. India whatever as regards the gneissic foundations of the peninsula, whereas this is the most noticeable fact of all through the great—through the enormous—thickness of the corresponding crystalline rock of the Himalaya.

Compared with variable gneissic rocks of S. India.

For all then who prefer to view this rock as simply an extreme effect of metamorphism of previously existing sedimentary rocks

[1] As recently found near the corundum mines, Sithampundi.

(which was Wynne's latest view) there is the ever-present difficulty of accounting for any sedimentary rock being of so uniform a mineral facies as to yield under the influence of metamorphism, even in its extreme form, a rock of such uniform characters throughout the range.

For those again who prefer to regard the rock as Archæan the difficulties are less, no doubt, but even they must admit a pretty thorough mixing of the material by some agency before it quietly found its way in an intrusive capacity among the ancient sedimentary rocks.

Its metamorphic action on the intruded rock.

Of not less importance in discussing this question are the metamorphic effects of this granitic or gneissic material on the intruded rocks. I take it as proved over and over again that such effects are to be seen in the Himalaya. Wherever sporadic appearances of this rock are examined such as lie well to the south of the main crystalline axis, whether the examples are taken from Hazara or from other places geologically visited in the Himalaya, they are always found as somewhat isolated elliptical areas and surrounded by a concentric zone of well-defined extra metamorphism.

The greater, more continuous masses of the higher peaks of course shew the same thing, but they are not so conclusive in their presentation of the true order of cause and effect as are these smaller detached areas of which the oft referred to Chor Mountain, Kalogarhi and Dudatoli may be taken as brilliant examples.

After what has been proved in the chapter devoted to the petrological descriptions of the crystalline and metamorphic rocks, I think it is hardly necessary to insist again here on the truly metamorphic character of the schistose strata; that they really do represent altered sedimentary rocks. That being the case, the extra metamorphism of a circular or elliptical zone surrounding the mass of the gneissose granite can only be understood as a result following on the appearance of the granite among them; and therefore that rock, whether called a gneissose-granite or a granitic-gneiss, has functionally acted here as an igneous intrusive rock.

Upward limit of the sedimentary rocks influenced by this metamorphism.

The next question before us is what was the upward limitation in the stratigraphical series of this metamorphic influence? What are the highest or youngest strata so affected? In Hazara that question has been partially answered. The Trias limestone we know to have been unaffected in this way; the Infra-Trias (whose age is uncertain) has been metamorphosed in a minor degree, but much if not all of this metamorphism may be attributed to the eruption of the basic dykes among them, an event which was of later date than the appearance of the gneissose-granite. The Slate series has, of course, been so metamorphosed. Hence the limit in Hazara is Pre-Triassic and possibly Pre-Infra-Triassic.[1]

In many parts of the Lower Himalaya the stratigraphical sequence of rocks from the secondary epoch downwards are unrepresented, and so no useful data can be supplied from the Indian side of the main range. But in the direction of Tibet on the north side of the great crystalline massif, as in Spiti, Garhwal and Kumaun, etc., the transitional metamorphic rocks (Haimantas and Vaikritas of Griesbach) are older than Devonian and possibly than Silurian. The great block of the historical strata that form the northern range of the Central Himalayan or Tibetan watershed, consists of shales, limestones, and sandstones, not only with a complete absence of granitic rocks intruded among them, but with all semblance of mineral change wanting in them too.

In Kashmir part of the Panjal system is described by Lydekker as having been metamorphosed, but, as has been shewn before when discussing the Infra-Trias conglomerate, it is possible that Mr. Lydekker's Panjal system is unnatural, inasmuch as it embraces two great formations separated by a conglomerate, which, in Hazara at

[1] Since the above was written, General McMahon in his most interesting Presidential address to the Geologists' Association, 1895, still upholds the Tertiary age of this granite. After what has been said above concerning its identity (undoubted I think) with the granite referred to by him, and concerning the Laichi Khun section, its Tertiary age is plainly impossible. Besides this, the most straightforward proof of such a conclusion is entirely wanting, namely the occurence of the granite intrusive among those Tertiaries at any single point from end to end of the Himalaya.

least, marks a great stratigraphical break and which, if equivalent to the Boulder-bed of the Salt Range and the Talchir bed of southern and Central India, similarly marks a line of great stratigraphical discordance. Again, Lydekker is very imperative in his assertion that in certain places the Panjal conglomerate is made up of rolled pebble of gneissic rocks and that they overlie the latter unconformably. At all events the metamorphism which these Panjal rocks have sustained is not greater than that which has affected the Infra-Trias of Hazara.

The possibility that the volcanic rocks of Kashmir (the amygdaloids) of about Silurian age are subærial representatives of the granitic cores must not be overlooked. Dr. A. Verchére we know held this view.[1]

As to the statements that the granite of the Himalaya invades the Upper Tertiaries in certain localities, as, for instance, in the low hills south of Naini Tal that has already been proved erroneous by me in a previous paper.[2]

Date of appearance of the gneissose granite at least Pre-Triassic.

On the whole then the age of the appearance of the crystalline core of the Himalaya, whether we consider it as a thorough granite or as a slumbering gneiss that at one time became functional as a granite, must be at least Pre-Triassic, whilst it is possible that it may be earlier even than carboniferous, *e.g.*, Silurian. At such and such a period then, thus limited, the hot plastic mass invaded the ancient sedimentary rocks, slates, quartzites, etc., and converted them into metamorphic schists; and this great event may possibly be considered as the first real step taken in laying out the foundations of the Himalaya.

Dynamic metamorphism of the Himalaya.

The subject of the pressure metamorphism of the Himalaya has already been touched on in the present chapter, when comparing the different aspects of the disturbance zones. The crystalline rocks of the northernmost zone of Hazara are those which have chiefly been affected. Enough instances, to illustrate the particular form of dynamic change operat-

[1] Journ., Asiatic Soc. of Bengal, 1867, p. 87.
[2] Mem., Geol. Surv. of India, Vol. XXIV, p. .

ing over such a wide extent of country, have been given in chapter II. This dynamic metamorphism of the crystalline rocks is, indeed, a very real thing, most striking to the geologist who visits the Himalaya for the first time. Every crag he comes across is remarkable for its parallel foliation and for its most evident fissibility. Every rock fragment he finds strewing his path is in the form of sheets and slabs for the same reason—in consequence of which such slabs are almost universally used by the natives for roofing purposes—though they are heavy material enough thus used. In addition to this, he may frequently wander for miles along river-beds and gorges with walls or rather banks of rock all round him absolutely so sheared and so powdered up that it is next to impossible for him to find sufficient sound rock to make a specimen.

Constancy over the full length of the Himalaya.

Just as the mineral composition of the great crystalline axis of the Himalaya has been found to be the same right through from end to end of the chain, so is it also found to be the case that the dynamic metamorphism of those rocks is also a constant factor throughout the range.

Its cause.

I do not think there can be two opinions as to the origin of this state of things. It can only imply a steadily acting lateral pressure of the earth's crust tending to bank it up against the central crystalline core by a movement and a resistance in two opposite directions. To the south we have the newer zones of disturbance shewing no dynamic metamorphism, but to the north the accumulated pressures consequent on the upheaval of several zones one after the other, with the gradually diminishing in size of the larger earth folds as the centre of the solid crystalline core is approached, have all tended to bring about that intense cleaving, shearing, and deformation of the minuter particles of the rock which I embrace generally under the head of dynamic metamorphism. There is no need, I think, to make any assumption as to the particular points of departure for the various stresses. From whatever points or lines they proceeded, their effects would be the same.

We have already seen, when considering the various zones, that beginning from the south we can find a gradual increase in the visible folding of the rocks as we pass from the most southern to the most northern zone. But it is only in the last, that is, the crystalline and metamorphic zone, that a change in the effects of the lateral thrusts of the earth's crust begins to be appreciable: the large visible folds at last give way, the beds flatten out more and more, and we must look now for these effects to the deformation of the intimate structural particles of the rock.

There is nothing anomalous in this: earth stresses at work in the younger zones of incoherent or but slightly consolidated rocks of varying texture and solidity, and with a great free surface above, naturally resulted in undulating folds of the same, varying in size and sharpness of the folding according to the epochs through which they have acted. At stated periods as we have seen, after a certain packing of the rocks had taken place, a great block of such rocks has yielded as a whole and gone sliding *over* the zone to the *south*, or *under* the zone to the *north*, producing a thrust-plane, and marking off two disturbance zones from each other.

But if we substitute the solid and uniform (internally) crystalline granite of the central axis in place of the ordinary strata of the southern zones, and if we believe (as we have a right to do from considerations as to the deep-seated nature of granite) that very great thicknesses of the slate or schistose rocks once overspread that crystalline core, we can understand that lateral stresses, if sufficiently powerful and long-continued, acting on such a material would be unable to violently fold and plicate them on a large scale, but would spend themselves in minute deformation of the rocks, in shearing, and in other ways characteristic of dynamic metamorphism.

Some peculiarities in the disturbance of the Himalaya.

It has sometimes been remarked that in the bottoms of deep glens and river-beds, the rocks show far more severe plications and other evidence of disturbance, than do the rocks or the heights rising thousands of feet above them. General McMahon once offered the suggestion that this might be due to much of the disturbance (packing

and folding) of the rocks having taken place subsequently to the carving out of the main river and stream beds, under which conditions the continuous zone of rock below and about the level of erosion would, of course, be thrown into folds, whereas the discontinuous hill-masses above would instead be simply brought nearer to one another as wholes without any, or at least so great, plication as took place below.

I cannot say that I have ever seen anything to prove such an hypothesis: but on the contrary, in Hazara at least, we possess clear proofs from the presence of horizontal gravels at all heights from 1,000 feet to 6,000 feet in the gorges and river valleys, and sometimes forming wide plateaux as at Hureepore, Abbottabad, and Mansehruh, that no such action has gone on so far back in the recent erosion of those gorges and valleys as is indicated by these grave banks.

A more probable reason in part I think to be the following: In traversing across, for instance, the southern part of the crystalline and metamorphic zone in a northerly direction, we pass from that part of the zone where the more visible effects of disturbance are manifest to that part where, owing to the resistance of the granite cores, the effects are confined to the minuter particles of the rock, as referred to under the last marginal heading. Another reason may be the superficial one already alluded to in the Dore R. (see p. 140) explicable as follows:—The recent elevation of Hazara (proved by the high level gravels) naturally brought about a commensurate deep cutting of the valleys in their lower parts producing great convex slopes steepening below. Such slopes are always unstable, especially along the lines of junction between rocks of different composition and massiveness, and hence the lower parts of such slopes offer all facilities for surface slipping and surface flexure on a large scale, producing an apparent greatly contorted state of the rocks. To such causes I believe to be due many of the subsidiary folds of the rocks borne on the larger folds. Such action may otherwise be regarded as a sort of 'settling'

of the more massive mountain blocks with steeply cut-away bases. In such a settling the upper parts would remain undisturbed, while the foundations by reason of being continually sapped by the streams, and from the superincumbent weight of the hill mass, would suffer distortion at their free and steep faces. Of course in such places no gravels would be preserved; they would be the first to be carried away by such a settling process, combined with active erosion.

Mountain systems of the Hindu Kush and Himalaya: their distinctness or not.

I do not propose to make any lengthy remarks on the subject indicated in the margin, as it is a little too wide to drag in at the end of this chapter. Moreover, detailed data are wanting over so much of the north-eastern parts of Afghanistan that anything like a proper appreciation of the subject is impossible.

The following points are more obviously connected with some of my recent work in Hazara and may be briefly alluded to.

Sudden change in direction of the strike at the Jhelum R.

The sharp bend in the strike of the strata at the Jhelum, and in the general run of the rocks and mountain ranges, from a N.W.—S.E. or W.N.W.—E.S.E. a S.W.—N.E. or W.S.W.—E.N.E. direction, following respectively the trend of the Himalaya on the one hand, and the Hindu Kush on the other, has been considered as a proof that here are indicated two systems of earth movement distinct in origin and perhaps in age.

The question as to whether this is so or not brings in many side issues equally important and equally difficult to settle.

Similar small changes in the Salt Range.

On a small scale, as in the Salt Range and many other places, we know how flexures of the rocks, perfectly parallel for considerable distances, will sometimes suddenly veer for a while through as much as a right angle, and then go on as before: although in the Salt Range no one would doubt for a moment that all the directions of strike, flexure axes, and lines of faulting there seen, and which pass continuously into one another, are parts of one single crumpling of the rocks along the south edge of the Potwar plateau.

A change of direction therefore, even a sudden one, in the trend of the axis of lines of disturbance need not always imply distinctness in origin and age.

Precise nature of the origin of earth movements unknown.

Of course so long as we remain ignorant of the precise nature and mode of working of the power which originates earth stresses, so long shall we grope about in more or less darkness in trying to solve a question such as this.

But the following considerations may be of some value in clearing the way for a better appreciation of the question so far as Hazara goes:—

(1) There is no sudden break along the Jhelum River in the lithological composition of the rocks of various kinds and of various geological ages. On the contrary I have shewn that in Hazara nothing is so remarkable as the way in which the lithological facies of many of the rock groups is identical with that of the Himalayan range. Mr. Griesbach (Geology of the Saféd Koh) has drawn attention to the same aspect of the question: petrologically and structurally the Himalaya and the countries to the west of the Jhelum river are the same. The latter states (p. 66) that the Hindu Kush from east of the Shiba pass to the little Pamir, with all the mountainous country to the south of it, including Kaffiristan, Chitral, Dardistan, Gilgit, North-West Kashmir, Swat and Dir, comprising a known area twice that of Switzerland is chiefly formed of old crystalline rocks which were land when the Trias (with coal) of Katagan and Afghan Turkistan was deposited. This wide belt of ancient rocks he considers as a western prolongation of the great Himalayan crystalline belt and that it, with the latter, was already foreshadowed as a great 'warp' of the older crystallines in very early palæozoic times. Considered geographically, or structurally, or causally, Griesbach believes the Salt Range and the

North-West Punjab hill ranges belong to the Himalayan area of elevation.

(2) It is clear, therefore, that if this identity of characteristics is sufficient to establish a general identity, then the sudden and rapid change in the strike and foldings of the strata at the Jhelum must be held to be a minor detail not of vital importance.

(3) It is only when we come to some of the later phases in the elevation of the Hindu Kush and Himalayan mountains that Griesbach finds a great difference between the two, inasmuch as in the Himalaya and North-West Punjab the miocene beds, coming immediately above the Nummulitic limestone, are of fresh-water origin, whereas on the Perso-Afghan side of the Hindu Kush the miocene is marine up to the upper miocene.

(4) I have shown it to be very probable that the Murree beds in Hazara and along the south edge of the Himalaya, east of the Jhelum, never extended very far away across the edges of the older disturbance zones to the north. Hence they were deposited in a great bay in the mountain mass which at that time was in existence and which corresponded to the present debouchure of the Jhelum. And yet we find the Murree beds on each side of the Jhelum have assumed strikes and folds strictly parallel respectively to the older zones rising above them, with the single exception of the peculiarity noticed, page 130. These facts seem to show that a mountain core having once been established will tend to maintain itself by influencing the direction taken by the younger zones.

Final remarks on the development of the Himalaya and their western continuation, as a whole.

In a previous memoir I have urged the probable great age of the Himalaya as opposed to the more popular idea that they were the product of yesterday, geologically speaking. The reasons I gave there, and the many similar lines of reasoning that I

have ventured upon in this memoir all tend in my opinion towards the same conclusion. But it is necessary here to do what I neglected to do in my earlier memoir, namely, to guard myself against misconception by defining what I mean exactly by such a statement.

Ever since our great pioneer in Himalayan geology, Mr. Medlicott, first examined and described the Sub-Himalaya in his memoir (Mem. G. S. of I., Vol. III); and since the Revd. O. Fisher wrote his far-seeing 'Physics of the Earth's crust' it has been gradually becoming evident to all who really examined the question in detail that the Himalaya are and have been in a constant state of change: a state of elevation along the main axis and depression along the mountain-foot, with intermediate zones of crushing, crumpling, and over-riding along shear and thrust planes. This is so evident that if one desired to be very particular one might say literally that the Himalaya of to-day are not the same as those of yesterday. But such a view of the matter would be valueless. Hence, in speaking of the Himalaya of a past geological age or epoch we mean, or at least I mean, that old representative of them which held about the same position and acted functionally in the same way as does the mountain-range going by the name of Himalaya to-day. It may not always have been of the same height as the Himalaya of to-day. It may sometimes have been represented by long parallel coast lines, or by archipelagoes with chains of mountainous islands following similar parallel lines, but that it kept certain original features, and that a mountain core recognisable in its unity, persisted through Tertiary, Secondary, and possibly into Palæozoic times, I have no doubt.

But whatever ultimate conclusion be come to in the future regarding these mountains, the moral of my recent work in Hazara seems to be that the more any part of the range is studied in detail the more impossible does the task appear of accounting for the presence of that lofty and complicated mountain mass, by any theory of sudden upheaval, whether by sudden we mean an upheaval occupying one or other age of the Tertiary period, or whether we take it in its still more wild and literal sense as being Post-Pliocene.

The study of the disturbance zones in Hazara seems to me to be convincing of the fact that the building of the Himalaya is not a matter that can be dismissed in a word as an essentially, and utterly modern, operation; but that each part has an interesting history of its own to tell, and that in the whole there are many such parts, the preparation and arranging of which shew on how vast a scale and from what ancient times the events of that as yet unwritten history have been shaping themselves and leading up to the most complex, stupendous, and beautiful natural phenomenon of the world. Rome was not built in a day, nor were the Himalaya either.

APPENDIX.

Economic Geology.

General.

Hazara like most districts of the Himalaya proper cannot boast of any very important mineral resources. The few economically useful geological products that may be noticed are enumerated below:—

Building stone: limestone.

Abundance of building-stone is naturally to be found in Hazara. The gneissose-granite splits readily into slabs, and trims into blocks sufficiently good for ordinary purposes. It has only been used in Hazara very locally however, for the reason that no large towns are situated in the crystalline zone. Some of the finely foliated rocks are used for roofing purposes The slabs are much larger than ordinary roofing slates, and also very much thicker, being from ½ to 1 inch in thickness.

The Trias limestone near Abbottabad and Hassan Abdal has been quarried constantly and successfully for building purposes. It furnishes a good durable stone but somewhat sombre of colour. The same rock, which is widely distributed in Hazara, can be obtained at many places.

In the southern parts of Hazara the Murree sandstones sometimes give harder courses of stone, which make an easily worked and fairly durable material.

Limestone for the making of lime is also widely distributed especially in the Slate and Nummulitic zones.

Iron.

Earthy hæmatite, in a bed some 5 or 6 feet thick, has been already referred to near Abbottabad as occurring associated with the felsitic breccia on the north-east spur of Sirban (p. 26). This would afford abundant material for smelting were plenty of fuel obtainable.

Martite—hæmatite pseudomorphous after magnetite—occurs at the base of the Spiti shales, but with the exception of some few localities, the band is a very thin one. Of similar value is the pisolitic iron-ore found near Hassan Abdal and on the gulee road at the position of the coal-bearing bed.

Gypsum.

Gypsum occurs under two different conditions. It is found associated with the Kuldana beds, as at Clifden near Murree, and in the gorge west of Doonga gulee; as well as generally in small quantities wherever the Kuldana beds are to be found (see map). But it is also found in the form of a bed or vein cutting through the Slate series at the following places:—(1) S.S. E. of Dowutta on the road along the Koonhar R. near Puttun Chhota, an isolated small exposure among slightly schistose slates striking N.N.E and associated with thin limestone beds in the slates. (2) In the form of a discontinuous but nearly regular outcrop as of a bed or as veins from near Bari-ka-Bugla by the "e" of Majhote, the "G" of Gahora, Kohree village, east slope of 6,462 feet hill to Bijora. It occurs mixed with ochre or buff-coloured shaly fragments, and with thin limestone bands, and is generally foliated or bedded or banded in grey and white. In all the outcrops, by their relation to the hill-slopes, etc., the rock suggests an ordinary bed, such as a bed of limestone dipping in towards the hill-mass. This may, however, be deceptive owing to movement of the hill side. On the other hand it seems to change its horizon somewhat among the slates, to cross them at a small angle, reaching the outcrop of the Trias limestone west of Badala, and then to leave it again and keep among the slates near Bijora.

The thickness of the bed or vein is not easy to calculate. It varies from 6 feet at Kohree to 50 feet at Bari-ke-Bugla and 100 feet west of Badala under the 6,462 feet hill. In the latter place, where it is thickest, it forms a prominent white and glittering cliff above the Trias limestone.

There must be a very great amount of the mineral present in the whole band.

Kaolin.

Kaolin or china-clay is reported from the higher parts of the Khagan valley, where it is doubtless formed by the decomposition of the felspar of the granites and allied rocks, but personally I know nothing of this mineral.

Gold.

Alluvial gold, in the usual small quantities as found all over India, occurs in the Indus valley near Kirpiliyan, where it is washed occasionally, as referred to on p. 251.

Mineral oil.

No traces of mineral oil are to be found in Hazara proper, but on the south border at the foot of the hills, ¾ mile north-west of Shaki-Noorpoor and also in Sydpoor town there are some springs which shew traces of oil on the surface of the water. I do not think they are of any practical importance; but here a test by digging and opening up the spring can only decide the matter beyond doubt.

At the former place the greenish coloured water of the spring (not flowing at the time of my visit) was covered by a thin film of brown oil which when taken off and applied to paper burnt with a spluttering noise and a sudden flashing flame. It was in the Nummulitic limestone and was the property of a 'Pir' or Mussalman priest who administered it as a medicine for sores.

At the latter place the spring apparently oozed out of a fissure in the same limestone in the village itself; but it was dry, with only a smell of oil, when I was there in the season, 1890-91.

Coal.

The coal of Hazara (details as to the age and stratigraphical position of which will be found in the body of this Memoir) has long been known in a general way. Mr. Morris, Executive Engineer in

charge of coal mines, North-Western Railway, writes that as early as 1883[1], it was found that the carbonaceous shale of the Dore valley could be used for lime and brick burning. Consequently a heading (Hewson's mine) was driven in the hill-side and soft coal obtained in an irregular seam 130 feet from the surface; 6,000 maunds were extracted and used as above described in Abbottabad after being made into slop-moulded bricks.

A second heading made in 1888 by the Public Works Department turned out 1,000 maunds after which water prevented further operations.

Mr. Hewson, Head Clerk to the Deputy Commissioner of Hazara, applied for rights to prospect for coal in certain parts of the road from Abbottabad to Murree, and spent a good deal of time and money in the enterprise when on furlough.

Reports by Mr. Morris and by Mr. Jones, Assistant Engineers, Hazara sub-division, were submitted giving maps of the known localities in the Dore R. and describing generally the lie of the coal as regards the neighbouring formations.

The former calculated that if worked systematically the coal could be raised at a cost of Rs. 6 per ton, and that the carriage to Rawalpindi would be Rs. 17 per ton, total Rs. 23. As Dandot and Bengal coal cost only Rs. 15 and Rs. 21 at the same place, it was concluded that the Dore coal could not compete with either of the latter at Rawalpindi on the North-Western Railway; but that if the projected Kashmir railway were ever carried along the valley of the Dore to Dhumtour, the prospects of the coal would be promising.

The chief difficulty in the way seems to be the variable quality of the coal.

Quality of the coal.

The first two samples sent by Captain (now Major) Abbott, R. E., District Engineer, to Calcutta for analysis, gave the following percentages :—

	1st Specimen.	2nd Specimen.
Moisture	17·78	1·90
Volatile matter exclusive of moisture	32·12	10·95
Fixed carbon	31·35	65·40
Ash	18·75	21·75
	100·00	100·00

and the sample sent by Mr. Morris to the Director, Geological Survey, Calcutta, gave the following analysis :—

	Per cent.
Moisture	0·32
Volatile matter exclusive of moisture	7·50
Fixed carbon	86·26
Ash	3·92
	100·00

[1] Memo. on the Hazara coal exploration in the neighbourhood of Abbottabad, 29th June 1889.

This percentage of fixed carbon seems exceptionally high, as the following analysis of the seam excavated by myself, 17 feet thick, at Begarmul near Juswal will make evident. The exposure was laid bare by Sub-Assistant Hira Lal under my direction and the samples taken carefully by myself at intervals of 1 foot.

No. 1.	Top first 4 feet.	% of ash	53·04
No. 2.	5 feet from top.	do.	58·70
No. 3.	6 „ do.	do.	37·12
No. 4.	7 „ do.	do.	54·52
No. 5.	8 „ do.	do.	37·60
No. 6.	9 „ do.	do.	35·20
No. 7.	10 „ do.	Moisture	5·20
		Volatile matter exclusive of moisture	11·80
		Fixed carbon	65·80
		Ash	17·20
			100·00
No. 8.	11 „ do.	% of ash	30·32
No. 9.	12 „ do.	do.	34·12
No. 10.	13 „ do.	do.	22·60
No. 11.	14 „ do.	do.	21·20
No. 12.	15 „ do.	do.	35·80
No. 13.	16 „ do.	do.	22·48
No. 14.	17 „ do.	do.	32·92
No. 15.	18 „ do.	do.	56·12
A selected specimen.		do.	22·20

From the above it will be seen that the average percentage of ash in the first 9 feet of 46·03 is altogether prohibitive. At the 10th foot there is a decided improvement, but below this the average ash percentage is again as high as 31·95 (see tri-monthly notes, Records, Geological Survey of India, Vol. XXVI, Pt. 3, p. 107), so that so far as this outcrop is concerned the coal would be of no use except for brick and lime burning. Whether it would improve towards the centre of the hill is a question for the engineer to settle.

Lie of the coal and broken continuity and variable thickness of the seam.

From many observations of this coal band and its constant associate the variegated sandstone at a great many places, it is my opinion, as stated in my preliminary note on the subject,[1] that though the band is continuous in a general way it has been so kneaded up with the shaly parts of the band, so sheared in places and crushed out into a thin bed here, and swelled out into a thick one there, that it cannot be relied on as occurring everywhere at its proper horizon in the sequence of the rocks.

[1] Rec. G. S. I., Vol. XXIII, pt. 4, 1890.

I have not been able to mark the coal band on the geological map with this memoir, because the scale of the map is too small, nor do I think it worth while, considering its variable quality and quantity, that any further details as to its position need be given here. In my previous report I have indicated its position in the Dore R. sufficiently well for practically testing its worth by some simple mining operations such as recommended by Mr. Morris. Until these are done, and a sufficient quantity of the stuff extracted to prove its worth or worthlessness as fuel from a practical point of view, it would be hardly advisable burdening this memoir with a special map showing its known distribution and probable course along the line of country to which it is confined.

All such information can be supplied at any time in the event of it proving of any real use as fuel.

INDEX TO PLATES OF MICROSCOPE SECTIONS.

Fig. 1. Gneissose-granite from Shal. n. between Kand and Seri, Black Mountain. Specimen No. $\frac{8}{881}$. Natural light, 1 inch objective. Drawn with *camera lucida* through a Dick's petrological microscope, as are all the sections which follow. *a* = orthoclase crystal shattered and deformed. *b* = quartz layers. *c* = garnet.

Fig. 2. Same as Fig. 1. Seen between crossed nicols. The polarized light brings out very plainly the 'cataclastic' structure in the quartz-felspar layers.

Fig. 3. Plagioclase-augite dyke (dolerite), $\frac{3}{4}$ mile north east of Mansehruh. Specimen No. $\frac{8}{808}$. Natural light. 1 inch objective. *a* = plagioclase, *b* = augite, *c* = titaniferous iron-ore. *d* = green alteration product.

Fig. 4. Epidiorite, near Mansehruh. Specimen No. $\frac{8}{811}$. Natural light, 1 inch objective. *a* = plagioclase, *b* = augite, *c* = titaniferous iron-ore, *d* = green alteration product.

Fig. 5. Epidiorite, dyke right bank of Indus river, opposite Ghazikot, Black Mountainy Specimen No. $\frac{8}{808}$. Natural light, 1 inch objective. *a* = rolled out plagioclase layers, *b* = eye of augite considerably altered, *c* = rolled out lenticles of titaniferous iron-ore, *d* = alternation product.

Fig. 6. Hornblende-schist, same locality as Fig. 5. Specimen No. $\frac{8}{808}$. Polarizer only $\frac{1}{2}$ inch objective. *a* = Quartz and secondary felspar? layer, *b* = hornblende, *b'* = Tremolite?, *c* = sphene.

Fig. 7. Hornblende-garnet rock, river boulder in Indus river bed. Specimen No. $\frac{8}{8}$. Polarizer only, 1 inch objective. *a* = Hornblende, *b* = garnet, *c* = titaniferous iron rock, *d* = rutile.

Fig. 8. Ultra-basic rock, River-boulder in Indus river bed. Specimen No. $\frac{8}{818}$. *a* = augite, *b* = olivine, *c* = hypersthene?

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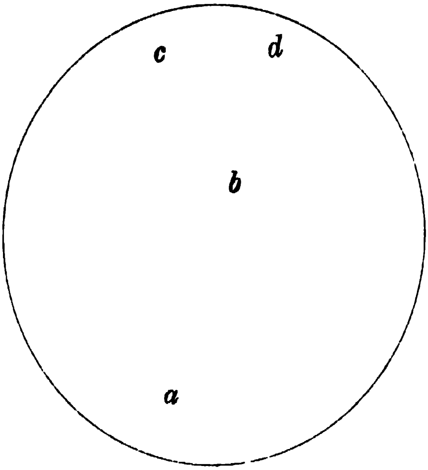

Fig. V.

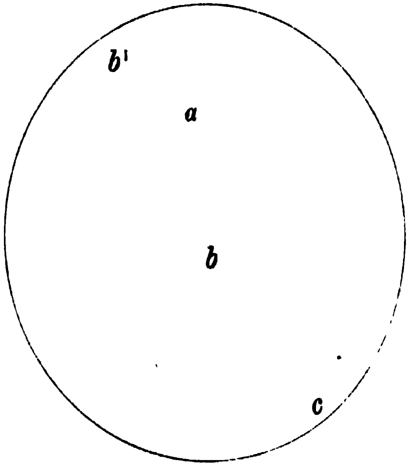

Fig. VI.

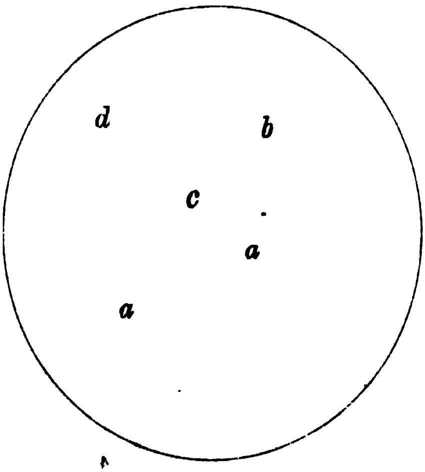

Fig. VII.

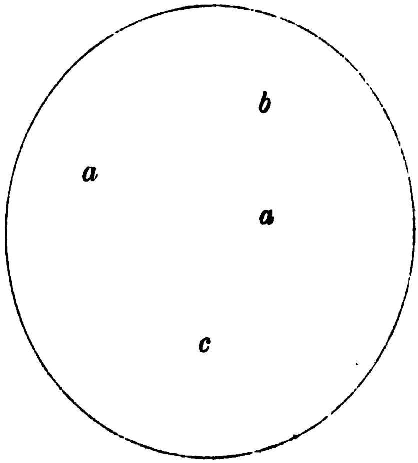

Fig. VIII.

Fig V

Fig VI

Fig VII

Fig VIII

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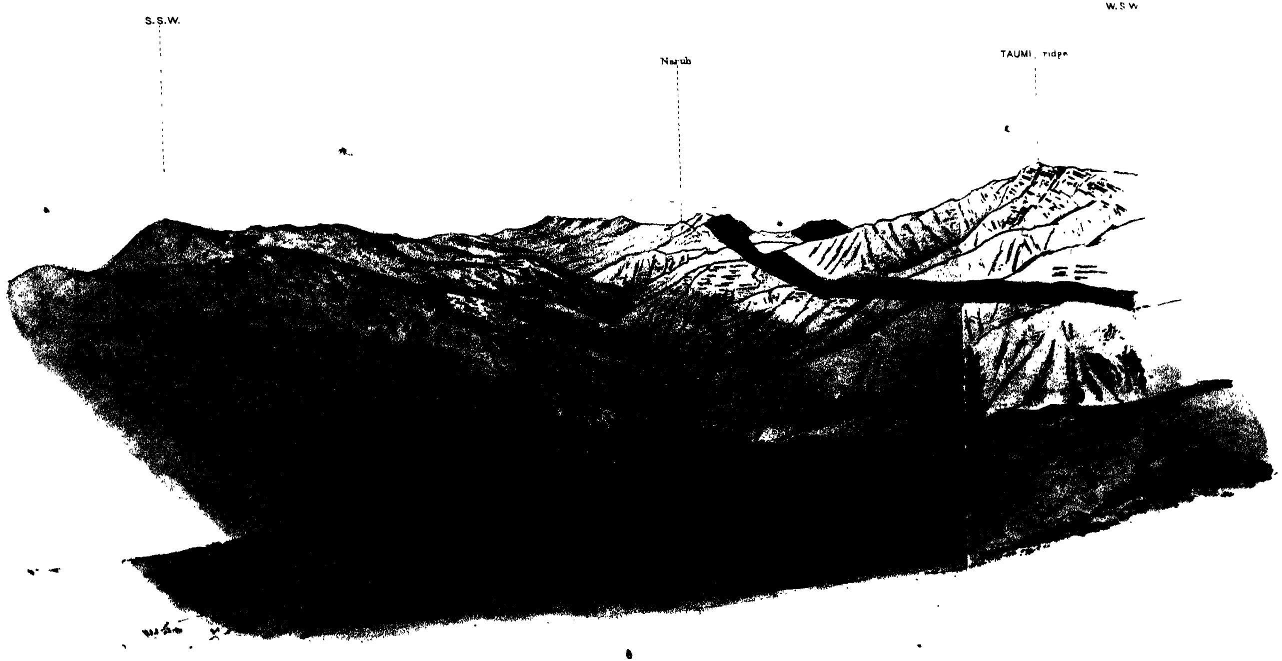

VIEW S.W. FROM NEAR KALABAGH.

Middlemiss, Hazara

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SIRBAN HILL FROM THE NORTH.

Middlemiss, Hazara

C. S. Middlemiss del.

LOOKING N.N.E. FROM ABOVE JUSWAL VILLAGE.

GEOLOGICAL SURVEY OF INDIA.

Middlemiss, Hazara

Memoirs, Vol. XXVI Pl. 8.

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VIEW SOUTH ALONG THE "GALIS" FROM MOORCHPOORI E. PEAK


Pujoeeur